SPACE SCIENCES LABORATORY

AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA USING REMOTE SENSING TECHNIQUES

A report of work done by scientists of 6 campuses of the University of California (Davis, Berkeley, Santa Barbara, Los Angeles, Irvine, and Riverside) under NASA Grant NGL 05-003-404

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PREFACE

In its broadest sense, the term "earth resources" pertains to all matter that is present at or near the surface of the earth, be it mineral, vegetable or animal. Thus it includes not only such relatively inert components as rocks, soil, water and air; it also includes such dynamic components as timber, forage and agricultural crops, as well as livestock, fish and wildlife.

The fact that these resources must be managed as wisely as possible has come to our attention with increasing forcefulness in recent years. A genuine sense of urgency, in fact, has resulted from our realization that the demand for these resources, whether on a local, regional or global basis, is rapidly increasing at the very time when the supply of many of them is rapidly diminishing or their quality is rapidly deteriorating. The increased demand is attributable only in part to the rapid increase in the world's population. In addition, the *per capita* demand for earth resources is steadily increasing. This increased demand is to be found not only among those who are affluent and whose appetites seem almost insatiable; perhaps to an even greater degree it is found among those with lower standards of living who are insisting, with increasingly strident voices, on having a more equitable share of the world's goods and services. We begin to comprehend the potential seriousness of the problem which is being brought about primarily through this "increased awareness of the have-nots" when we reflect on the fact that, as of today, the world could only support 600 million people if the *per capita* resource demands of all of them averaged

the same as in the United States. In that event, approximately 5 out of every 6 of the earth's present human inhabitants would have to be considered as "excess population" and anything short of "zero population growth" in the future would so aggravate this basic problem that man could not be long for this world.

The situation which has just been described has prompted one high U.S. official recently to proclaim that "man soon will be confronted with one of the most serious crises in his existence". Since it is, indeed, a situation calling for the wisest possible management of the earth's resources, we would do well to ask whether any developments in science and technology are occurring which might facilitate such management. As this progress report will indicate, several such developments are occurring in a rapidly growing field known as "remote sensing".*

The rationale by which remote sensing of the earth's surface can lead to wise management of the earth's resources is not a complex one. In fact it can be expressed in a simple two-part statement, as follows:

1. Wise management of these resources is greatly facilitated if timely, accurate inventories of them are periodically made available to the resource manager so that he will know at all times "how much" of "what" he has "where".

2. Almost invariably the making of such inventories can be greatly facilitated through the use of modern remote sensing techniques by means

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[1] The term "remote sensing" pertains to the acquiring of information through the use of cameras and related devices (e.g., radar and thermal infrared sensors) operated from aircraft and spacecraft which are situated at a distance from the features that are being sensed.

of which photographs and related records about these resources are obtained periodically from aircraft and spacecraft. The favorable vantage point offered by these two kinds of vehicles is of great importance. Since the face of the land looks to the sky, it often is the view of the earth's surface as obtained from an aircraft or spacecraft which can best provide the resource manager with the information that he needs.

The need on the part of the resource manager for accurate resource information is most clearly seen when we consider that the wise management of earth resources usually requires the implementation of a 3-step process: inventory, analysis and operations. Ideally, in the inventory step an accurate determination is made as to the amount and quality of each type of earth resource that is present in each portion of the area that is to be managed. In the analysis step, certain management decisions are made with respect to these resources. This is accomplished for each portion of the area by considering, on the one hand, the nature and extent of the resources (as previously established in the inventory phase) and, on the other hand, the "cost-effectiveness" or "cost-benefit ratio" for each management alternative which might be exercised with respect to these resources. In the operations step the resource manager implements each management decision that has been made in the analysis phase. He does this, for example, by applying certain fertilizers and pesticides to an agricultural crop, or cutting the overmature trees in a timber stand, or practicing "deferred rotation grazing" in certain parts of a rangeland area, or building a dam of a certain height at a

particular point in a stream channel, or promptly extracting any economically valuable minerals which are known to be located in a stream bed that soon will be so deeply flooded by construction of a dam as to make subsequent mining operations extremely difficult if not impossible.

The study dealt with in this Progress Report seeks to apply the foregoing concepts in the making of an integrated study of earth resources in the state of California using remote sensing techniques. Many of the earth resource components in California, as in most other parts of the world, are dynamic rather than static. Therefore, it is necessary for these resources to be inventoried frequently and rapidly -- frequently so that resource trends can be followed -- rapidly so that resource management decisions can be made and implemented while the inventory data are still current. Our present studies, based largely on NASA-flown photography, are giving major emphasis to such considerations. These studies give particular consideration to the opportunities that currently are being afforded for satisfying these requirements through the use of data being acquired by the first Earth Resources Technology Satellite (ERTS-1).

The wise management of earth resources in an area such as the state of California depends, however, on far more than the mere acquiring of timely, accurate resource inventories. Even when given such information, the resource manager could easily make wrong decisions if he were to ignore certain important socio-economic factors. Alternately stated, human needs and emotions cannot be overlooked (particularly in these

days of the environment "crusaders") as we seek better to manipulate earth resources, whether on a local, regional, national or global basis.

As will be indicated in the present progress report, due consideration is being given to each of the foregoing factors in this "integrated" study.

Robert N. Colwell
Principal Investigator
January 28, 1973

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Chapter 1

INTRODUCTION

In 1969 several joint sessions were held among scientists on 6 campuses of the University of California who were interested in conducting remote sensing research under NASA's Earth Resources Survey Program. The participating campuses, listed in succession from the northern to the southern part of the state were Davis, Berkeley, Santa Barbara, Los Angeles, Irvine and Riverside. The scientists prepared several remote sensing proposals dealing with topics which ranged from the global monitoring of volcanic eruptions to the study of aerosols in the atmosphere. Among these was a proposal to conduct an integrated study of California's entire "resource complex" through remote sensing from aircraft and spacecraft.

Of these various proposals, only the latter led to funding by NASA, the first allocation of funds having been made in May, 1970. From the outset, half of these funds have been contributed by the NASA Earth Resources Survey Program and half by the NASA Office of University Affairs, but with a substantial amount of matching support provided by the University of California. Coordination of the study continues to be provided by the Space Sciences Laboratory which is located on the University's Berkeley campus.

Since its inception this study has been given the rather cumbersome but aptly descriptive title: "An Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques". Reasons for

selecting the state of California for the test site included the following:

1. It exhibits a great variety of earth resources, landforms and climatic factors.

2. Large amounts of remote sensing data and associated ground truth data already are available for many parts of California.

3. With respect to earth resource management, various social and environmental stresses already are being felt strongly, making California a model of things to come, both nationally and globally.

4. Many competent investigators were known to be residing in California and available for assignment to such an integrated study. In fact several of them had been performing research under the NASA-funded Earth Resources Survey Program almost since its inception in the mid-1960's.

5. Appropriate NASA-funded facilities which had already been established in California (such as the Space Sciences Laboratory on the Berkeley campus of the University of California, and the NASA-Ames Research Center near Sunnyvale, California) were known to be available to provide administrative and monitoring support, as necessary, for any sizeable integrated study that might be conducted within the state.

6. The State of California, being a political entity, can readily make and implement resource management decisions of the types which might be arrived at in the light of information acquired through our integrated study.

1.1 EARLY PHASES OF THE STUDY

It was recognized in our initial proposal to NASA that little would

be accomplished under this integrated study if we attempted to investigate, at the outset, all components of California's entire earth resource complex, statewide. Ideally we would begin our study by investigating some discrete phase of this complex which, although of limited scope, would require a consideration of both the resource interrelationships and the attitudes of the people in a very sizeable part of the state. Given these constraints and ambitions we tentatively selected the "California Water Project" as the focal point for the initial phase of our study. The word "tentatively" is used advisedly because it was recognized that resource managers and administrators, particularly within the Administrative Branch of the State of California, would need to be consulted in order to determine (1) whether such a study would meet with their favor or disfavor and (2) whether, in the event that we were authorized and funded to conduct such a study, mutually beneficial working relationships with resource managers in the Administrative Branch might be developed.

Initially there were some serious reservations expressed by certain personnel in the Administrative Branch as to the advisability of our conducting any study, whatsoever, that might relate specifically to the California Water Project. They pointed out that most of the decisions that were required both in conceiving and in developing the California Water Project already had been made long before our study was proposed. We were well aware of this fact and had been regarding it as a major strength rather than a weakness in our proposed study, since our objective was not to provide a "critique" of either the concept that resulted in authorization of the California Water Project or the steps being

taken to implement it. Instead, we were hoping to be able to use in our proposed study the valuable experiences gained and "ground truth" data acquired by those who had been working for many years on the California Water Project. We realized that it would be prohibitively costly and time consuming for us to attempt to acquire this same kind of "input" independently. However it was our belief, as expressed in our proposal, that this situation enhanced the usefulness of the state of California as a "calibration" site, so that our research findings could be applied, by extrapolation, to other parts of the world that were less developed than California, yet highly analogous to it in terms of characteristics of the total resource complex. By the time these discussions had been concluded, an amicable relationship with the Administrative Branch and been developed and this fact was made known to the appropriate NASA authorities at the time when final consideration was being given to our proposal.

The emphasis that has just been given to matters of "protocol" is a highly purposeful one. For it seems quite possible that the future success for the entire NASA-sponsored Earth Resources Survey Program, especially as it approaches a semi-operational phase, could depend in very large measure upon the extent to which attention is given to such matters by the various NASA-funded investigators. Resource managers are subjected to ever-increasing amounts of criticism by those who seek to command attention by being so bold as to "second-guess" the wisdom of certain resource management decisions. These critics range all the way from a certain group of discourteous antagonists known as "eco-freaks" to individual politicians who are almost desperately in search of issues

which will constitute suitable planks in their platforms. In the presence of such potential criticism, many resource managers are becoming increasingly sensitive about the kinds of resource surveys that should be permitted. Criticism, or even the prospect of it, can beget counter-criticism, and the age-old maxim that "the best defense is a vigorous offense" can prompt some resource managers to seek to discredit at the outset any individual or group who seemingly is about to delve into their affairs. To ignore this fact in future studies conducted under the NASA Earth Resources Survey Program might be to ensure at the outset the ultimate failure of such studies -- and the more closely these studies become of operational significance, the greater the likelihood that attempts will be made to discredit them.

1.2 RECENTLY IMPLEMENTED PHASES OF THE STUDY

Although certain aspects of our initial study (dealing with the California Water Project) are continuing, we have recently undertaken a study of certain other phases also. Notable among these are studies by the Berkeley, Santa Barbara and Riverside campuses dealing with coastal resources and coastal phenomena. It has been pointed out to us by personnel of the California Resources Agency that approximately 80 percent of the people of California live in the Coastal Zone. This fact suggests that the many conflicting proposals for use of the resources in this zone might better be evaluated in the light of information derived through remote sensing studies such as ours.

As previously indicated, much of the criticism relative to the present management of California's earth resource "complex", including its Coastal Zone resources, has been levelled at decision makers in

California's Administrative Branch. Much of it also appears to be unwarranted. There is increasing evidence that remote sensing techniques of the type which our group is developing will be useful in portraying, more clearly than has ever been possible before, certain types of information which are highly relevant to the management of California's resources. In this way much of the unwarranted criticism should be alleviated, and solutions to such problems as may be the subject of warranted criticism, more readily found. An increased realization of these promising possibilities helps to account for the increased degree of cooperation being achieved between our scientists and those of the California Administrative Branch. The achieving of such cooperation is so central to the success of our integrated study that two examples of it will be given here: (1) Our group has just submitted to NASA a follow-on proposal entitled, "An Integrated Study of Earth Resources in the State of California Based on ERTS-B and Supporting Aircraft Data". California's Lt. Governor Reinecke, in commenting upon our proposal in his letter to NASA authorities stated:

> "On behalf of the State of California, I wish to take this opportunity to strongly endorse this proposal. The basic research which under this proposal would be performed by a highly competent group of University of California scientists, would yield valuable information through which better resource management data, so valuable and important to our rapidly developing state, could be utilized. As further evidence that the State of California is vitally interested in using ERTS type data in resource management, a second proposal (which will indicate quantity and recommended locations from which ground truth data will be provided) will be submitted to NASA directly from my office on behalf of the administrative branch of the State of California. This second proposal entitled, 'A State of California

Study Combining Basic Research and Applied Use of ERTS-A Data for More Effective Resources Management', is being prepared in close cooperation with scientists of the University of California and is complementary rather than competitive with the University's proposal . . . Mr. Norman B. Livermore, Secretary-Resources Agency, and Mr. Searles, Secretary-Agriculture and Services Agency, who represent the largest segments of state government utilizing this data, and who have contributed guidance and impetus to the proposed program, will provide further leadership and assistance as required."

(2) In recent months, several of the training courses which have been taught by scientists from our multi-campus project have been attended primarily by scientists from California's Administrative Branch who seek to learn how they can most effectively use data of the type which ERTS and "highflight" imagery will provide, the better to manage California's natural resources.

1.3 TYPES OF INTEGRATION BEING SOUGHT IN THE STUDY

We are making a sizeable effort to achieve "integration" in our study from three standpoints, data acquisition, data analysis and data use as indicated in the three paragraphs which follow.

From the data acquisition standpoint this study seeks to integrate: (1) data acquired from sensors operating in several wavelength bands (the Multispectral or Multiband concept); (2) data acquired from sensors operating at several different times (the Temporal or Multidate concept); (3) data acquired from two or more stations in the same flight path (the Parallax or Multistation concept); (4) data acquired using both like- and cross-polarization sensors (the Multipolarization concept); (5) data acquired from two or more nearly identical images (the "improved signal-to-noise" or Multi-image Correlation concept); and (6) data acquired from space, air and ground (the Multi-stage concept).

From the data analysis standpoint this study seeks to integrate: (1) analyses contributed by analysts from several disciplines (the Multi-disciplinary concept); (2) analyses made possible through the making of various optical and electronic image enhancements (the Multi-enhancement concept); and (3) analyses made possible through proper interaction between humans and machines (the "Human" vs. "Automatic" or Multiple Data Processing concept).

From the information use standpoint this study seeks to integrate: (1) information about all components of the total resource "complex" and the inter-relations of these components (the Multi-resource concept); (2) information needed in producing several kinds of earth resource products from the same piece of property (the Multi-use concept); (3) information needed by several types of earth resource managers and consumers (the Multi-user concept); (4) information displayed in various formats (thematic maps, 3-D models, annotated photo mosaics, tables, graphs, etc.) to best satisfy the various multi-use and multi-user requirements and preferences (the Multi-display concept); and (5) information about inter-relations among earth resource components and the uses of these components in one geographic area vs. another (the Multi-association concept).

While this "multi" concept could be still further enlarged upon, perhaps it already has been overdone in the preceding paragraphs. Nevertheless, at the very heart of our integrated study is the central theme implied above and expressed as follows: The providing of useful information about earth resources through the use of remote sensing techniques

is, at best, a difficult task. In fact, it becomes an almost futile task if only one image of the area of interest is given in the completely unenhanced form, to one analyst, and he uses only one approach in attempting to extract information from it that might be of use to only one of the host of potential beneficiaries of such information. In contrast with this limited approach, each of the "multi" concepts just expressed may add a small amount to his ability to improve the usefulness of resource information that he is attempting to provide. Furthermore, the overall usefulness of the final product may be improved far more than might be suggested merely by summing up the improvements made possible through individually employing these various "multi" concepts, as appropriate. Hence, at some point in the process a threshold is crossed, to the left of which the information acquired by remote sensing is virtually worthless and to the right of which it becomes progressively more useful, even to the point of becoming the most useful combination of tools and techniques available to those interested in achieving the wisest possible management of this globe's critically limited complex of earth resources.

Chapter 2

DEFINITION OF EARTH RESOURCE POLICY AND MANAGEMENT PROBLEMS IN CALIFORNIA

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2.1 INTRODUCTION

Under the Integrated Study, our Social Sciences Group has a number of objectives: (1) to ascertain the present functions and methods of operation of the various Divisions of the State Department of Agriculture; (2) to identify those which could ultimately utilize ERTS and other remote sensing data in performing their activities; (3) to determine in specific terms the "climate of acceptance" for remotely-sensed data; (4) to investigate and assess the user potential of ERTS as envisioned by resource managers in government; and (5) to study the ways in which data enter into the resource management decision process, the latter with a view to learning how data derived from remote sensors could affect and, perhaps, improve the process.

2.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

During the period under review, the Social Sciences Group has made significant progress toward accomplishing its goals as part of the Integrated ERTS Project. As was reported earlier, the California Department of Agriculture was selected as a potential beneficiary of ERTS data. This is consistent with the official statement of the National Academy of Sciences Committee on Remote Sensing for

Agricultural Purposes: "For resources to be managed wisely, there must be accurate and timely information, and remote sensing from aerospace platforms to provide quantitative data from which large amounts of needed information can be extracted. Much of this can be made available not only to responsible officials but to the public at large."*

The initial phases of the work took the form of a canvass of the various divisions of the State Department of Agriculture with interviews with key personnel. Entree and excellent working relationships were gained and established through the cooperation of Mr. Earl Davis, the State Coordinator of Remote Sensing, and the active participation of Dr. Gordon F. Snow, Acting Director of Agriculture for the State.

Our study, which began before the July, 1972 launching of ERTS, has established "ground truth" in the socio-political arena. In other words, we have become familiar with the terrain so as to be better prepared to observe the uses to which new data are put and, eventually, their effects. It can be noted, at the outset, that the official "climate of acceptance" in the State Department of Agriculture assures a ready welcome for ERTS data.

As early as 1937, under enabling legislation known as the California Marketing Act of 1937, aerial surveys were made of peach orchards as a means of carrying forward estimates of yields and production. Some of the very same government officials and industry representatives

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*National Research Council, National Academy of Sciences, Committee on Remote Sensing for Agricultural Purposes, <u>Remote Sensing, with Special Reference to Agriculture and Forestry</u>, 1970.

instrumental in these earlier efforts have now "graduated" to the conceptual level of ERTS. In the 1967-68 Biennial Report of the California Department of Agriculture, the Bureau of Agricultural Statistics, which operates jointly under State and Federal sponsorship, referred specifically to the use of aerial photography in determining fruit acreage inventories and indicated ongoing experimental work in the mapping of fruit and nut plantings in several countries.

W. Ward Henderson, Chief of the Bureau, suggested that in addition to the more obvious benefits that might possibly flow from ERTS and other remote sensors, information that would yield <u>earlier</u> and <u>more reliable</u> forecasts and estimates of production could have a profound effect on industry strategy and politics. By taking some of the guesswork out of the bargaining procedures between growers and processors, ERTS data might lessen tensions. Ultimately, refinement of crop estimation and, consequently, more efficient planning, with processors' risks lessened, could have a stabilizing effect on the bargaining and marketing processes. Mr. Henderson foresaw as a primary outcome a clearcut benefit to the consumer of agricultural products.

While increasing competitive pressures in agriculture and continued emphasis on marketing have heightened the demand for improved statistical data, "the basic information is still obtained on a voluntary basis from farmers, stockmen, hatcheries, dealers, processors, warehousemen, transportation firms, merchants, marketing organizations, and others"*

*State of California, Biennial Report, 1967-1968, California Department of Agriculture, pp. 68-9.

identified with the State's agricultural industry, as well as from County Agricultural Commissioners. It is the view of an official in the Division of Marketing and Services that some of the main sources of current information cannot be relied on. Supplying the data is tedious and costly; if a marketing order were terminated with cessation of surplus control, the affected industry would probably curtail its reporting. If this were to occur, serious gaps would develop in the data. Against such a contingency, the repetitive and continuous aspects of ERTS reporting offered a promising antidote. Moreover, the advantages of continuous reporting become clear when one observes the long-range effects of orderly planning in the production of food. From the orchard to the grocery basket, every step in the chain is in a dependent sequence, and miscalculations and poor synchronization are costly. It might well be that the ultimate beneficiary of ERTS data, intelligently utilized, would be the consuming public.

The Bureau of Plant Industry, especially in both its Control and Eradication and its Exclusion and Detection Divisions, has a long history of interest in remote sensing techniques. Dr. Gordon F. Snow, Special Assistant to the Director of Agriculture, prepared a proposal three years ago for the use of remote sensing capability in detecting plant diseases, specifically, yellow leaf roll virus in peach and nectarine trees and branched broomrape in tomato plants. The Bureau of Plant Industry is especially concerned with the uses of ERTS. In fact, the staff assistant to the State Coordinator of Remote Sensing, is a plant pathologist (Dr. David Adams), formerly with that Bureau. Dr. Adams works closely with members of our Integrated ERTS project,

notably with the Remote Sensing Laboratory and with the Social Sciences Group. He anticipates that the survey work eventually accomplished through remote sensing will be cheaper and better than that now achieved through field work and that, through this change of orientation, specialists will be released for more important analytical tasks. At present, Dr. Adams is developing an experimental control project on a virus problem in the Ventura citrus groves. Both the University of California Remote Sensing Laboratory and the NASA-Ames Research Center have been consulted, since there appears to be the prospect for a combination of ERTS and U2 low flight photography. With grower associations having evinced interest in the project, this experiment could provide a useful model for genuine integration of activity at all levels, from NASA through to the public.

As background for the data utility assessment that at some appropriate later date must be made, we have gathered research materials on the uses of ERTS by other experimenting groups and at other sites. In the available reports, there seems to be considerable preoccupation with technical details, e.g., equipment for data analysis and arrangements for ground reconnaissance. "Progress" is limited to the acquiring of personnel or assigning of tasks. The situation in California seems considerably more advanced. Favored by nature, California produces on a commerical basis some 200 agricultural products, under tremendously varying conditions -- from North to South, and from high to low elevations, with extremes of temperature. With agriculture its foremost industry, the State's Department of Agriculture is a highly respected body with a long history of high

professional standards. From the view of high level policy as it pertains the State, reference should be made to the State Board of Agriculture, which is appointed by the Governor as advisory to him. The chairman of this Board is an ex officio member of the University of California Board of Regents. These details are provided as an indication of the State of California's explicit recognition of the importance of its agriculture and, for our specific and proximate purposes, as the structure with and within which we are working in our ERTS endeavors.

Not surprisingly, in view of California's sophistication in matters agricultural and because of its history with respect to remote sensing, we have encountered considerable interest in ERTS, as well as a substantial degree of open-mindedness on the part of potential users. If there exist the traditional bureaucratic resistance and recalcitrance toward innovation, there is no evidence to that effect at this early stage. What seems to be imminent, however, is the danger of an oversell created by a small sector of enthusiasts whose optimism has caused them to overlook the enormous gap between ERTS imagery and usable information. The disparity between the confident speeches and treatises about ERTS and related technologies as likely instruments for revolutionizing the management of plant, soil, and water resources and the reality, i.e., "ground truth," becomes dramatically evident when one moves out of the laboratory and into the field. While there is high-level preoccupation with the technology of remote sensing and considerable advance in the state-of-the-art, little attention has been paid to the mechanisms by which ERTS data could be moved into channels readily accessible to

users. That this is not exclusively a California problem but rather, one that characterizes the ERTS program is suggested in the State of Ohio report (July 1972).*

There, problems arose at the very elementary level because of the need by certain individuals for precise information as to when the spacecraft would pass over specific areas in Ohio. In California, no such lack exists. Considerable publicity has been given to ERTS activities and to the likely benefits to be derived from them. But there exist no direct channels for disseminating information to the potential user. The connection between the scientific experimentation and the users of ERTS data usually is poorly defined or nonexistent. For example, the U.S. Department of Agriculture issued a news bulletin (May 26, 1972)** that hailed the launching of ERTS-A as "an important step in helping agricultural scientists develop better technology to manage plant, soil, and water resources." Then follows a description of ERTS: "ERTS-A will gather information on vegetation, soil, and water faster than it can be gathered with aircraft or ground observations." The four experiments by the Agricultural Research Science are then described. The bulletin then concludes with these words: "No one can accurately assess the value of remote sensing for world agriculture. It is estimated that in the United States alone, fire, insects, and disease cause $13 to $20 billion in losses annually. Early detection of

*State of Ohio, Department of Development, Relevance of ERTS to the State of Ohio, N72-29273, July 1972.

**U.S. Department of Agriculture, News, USDA-1783-72.

these enemies could provide for more timely application of effective control measures and thereby reduce the magnitude of losses." These noble generalizations fail to recognize the ground truth. In California, for example, the channels by which ERTS information can be disseminated have not yet been clearly defined, nor have the bureaucratic mechanisms that can expedite the process of information transfer.

Our research leads us to believe that information dissemination, as conceived by the architects of the ERTS program, does not officially include users at all. The data flow stops with the Principal Investigators, who are not users, but in the final analysis, technical middle men. While these people play an important role, the real test of ERTS lies beyond them, in an unstructured, unmapped no man's land. Here exist the users, whose experience should, optimally, provide NASA with feedback to guide the evolution of future satellite systems. If ERTS is to achieve its promise, it will be through the activities of the <u>users</u>, be they government agencies, grower groups, or private individuals, and not the technical specialists.

In this respect, the conclusion of an OECD Working Group of Scientific and Technical Information are pertinent:

> The effectiveness of human activities can only be assessed on the basis of a complete chain of events, which passes from scientific knowledge and its creation, through the stages of technical research and through many many complex decisions, to the production of goods or service, integrated into an economic and political system. Exchange of knowledge is needed within each group of men concerned at each stage of this chain;

> it may need translating into another "language" for transfer to other groups engaged in other tasks.*

The Working Group concluded that the spectacular success of development in Japan was due in large part to the "efficiency of their knowledge transfer mechanisms."

For us who are observing at first hand growing sophistication in the acquiring and storing of information but a dearth of skill in implementing its full utilization, these findings have special import. Our contacts with a large number of government agencies reveal the problem of information management, in the sense of interpretation, transfer, dissemination, and utilization, as crucial to the ultimate success of and support for ERTS. It is for this reason that we state our research findings, even at this relatively early stage, in such emphatic terms. We are convinced that the communication lack is a severe deficiency in the overall ERTS program and, in fact, have devoted some of our efforts to ascertaining the ways in which ERTS data could ultimately be put into public service. Besides our work with government agencies, we have begun making contact with grower associations. We have learned that they might be a potent force in getting certain Divisions of the State Department of Agriculture to take a more active role in acquiring and using ERTS data. Our primary contact to date has been with the California Canning Peach Association. At a meeting with that group on December 1, Professor Robert N. Colwell, Principal Investigator of the Integrated Project made a presentation about ERTS technology, its potential, and its limitations. Dr. Ida R. Hoos, of the Social Sciences Group, pointed out how the farm organizations and commodity groups

*Organization for Economic Cooperation and Development, Information for a Changing Society, Some Policy Considerations, Paris, 1971, p. 13.

could serve as an important medium of information exchange and communication. In the discussion which followed these presentations, members of the Association showed genuine enthusiasm for accepting these new technological developments, but considerable mystification as to how they might put such developments to practical use. One of the most promising applications appears to be that of minimizing early spring frost damage to peach orchards by using ERTS-1 data to help monitor the soil moisture status of each orchard. If the soil moisture is maintained above a certain level, the likelihood of forest damage is greatly reduced. The stage was set in this first meeting for many profitable discussions at future meetings, both with this and with several other "grower" groups.

2.3 PROPOSED FUTURE WORK

Building on the review that we have made of the respective Divisions of the State Department of Agriculture, our Social Sciences Group intends to explore further the specific ways in which these government bodies have used or conceive that they can in the future use ERTS data. Herein lies the way that the technology of remote sensing can be assessed in realistic terms. Since putting the technology to useful work is one of NASA's basic goals, this research is both goal- and action-oriented. The State of California, with its enormous variety of products and diversity of growing conditions, has provided an appropriate test site. Observations relative to uses which can be made of ERTS-1 imagery, in all its manifestations and ramifications, can provide lessons in the immediate applicability not only throughout the United States but in other countries as well. Some agencies in the State of California have begun, through the University of California's

Remote Sensing Laboratory and with the active participation of its technical specialists, to experiment with ERTS imagery as a source of information to help them carry out their functions. How this information is put to use within State Government and its real and anticipated effects on decision-making processes with respect to resource management will be studied and reported.

We plan also to carry forward the work we have begun with farm organizations. Because they traditionally have served as a vehicle or channel through which information is delivered to the farmers and growers, they must be recognized as a vital link in the communications chain between ERTS and the ultimate consumer. We want to ascertain whether and how ERTS data can become a useful input in the California State Department of Agriculture's functioning and, moreover, in the farmer's production function. We expect, further, to learn, through experimentation now underway, whether aerial photography might serve a more immediate need. The greater resolution available through high altitude flights, as compared with satellite imagery, might yield more useful results, at least in certain types of agricultural survey work.

To assess the advantages and disadvantages, benefits and shortcomings of remote sensing-derived data, we will continue our field studies of the State Department of Agriculture and of the grower associations most likely to be responsive to new management modes and to new sources of information -- ERTS and aerial. As before, we will continue to cooperate with the State's Coordinator of Remote Sensing, Mr. Earl Davis, and with his assistant, Dr. David Adams. As always, we will draw upon the technical expertness of

the Remote Sensing Laboratory at the University of California and will, wherever appropriate, work in conjunction with the specialists from the various campuses.

We observed earlier that there is a marked discrepancy between the attention being paid to the technical aspects of ERTS and the interest in exploring applicability and testing utilization. This has contributed to a wide gap between the technological sophistication of ERTS and the capability of socioeconomic mechanisms to receive and use the data, even if only on a trial basis. While the resulting mismatch might be expected and accepted at early stages of ERTS, its persistence could be detrimental to its objectives as stated by Mr. Charles W. Mathews at the time of the ERTS launching. These objectives were <u>user-oriented</u>. Our intention, therefore, is to move forward in the attempt to link the users into the communications chain. Connecting the observing capability of earth resources satellite and other remote sensing technologies to the nation's food producers constitutes an important step in assuring the success of and public support for NASA's efforts. This is a matter which the Social Sciences Group will continue to explore and, wherever possible, implement.

Chapter 3

USER REQUIREMENTS FOR THE APPLICATION OF REMOTE SENSING IN THE PLANNING AND MANAGEMENT OF WATER RESOURCE SYSTEMS

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3.1 INTRODUCTION

The course of this investigation toward use of remote sensing as a new tool in the routine activities of water resource planning and management groups in many private and public entities has followed a three-stage development. As reported in two previous annual summaries and progress statements, users' needs for hydrologic information were determined and classified into categories under headings listed as components of the "runoff cycle".

Secondly, these components were identified as subsystems of a generalized hydrologic system. The elements were then resolved into two classes of informational needs; namely, operational parameters, and specialized parameters for research and development. The former class has a broader and possibly synoptic character in comparison with the latter and, in many instances, represents the kind and form of information most necessary for direct application to large scale resource operations as well as to planning functions.

Within the parameterization framework, the resolution, frequency, type and form of data were outlined, and a sample of standard methodology in current usage was noted. And finally, the "state of the art" method and spectral region for remote sensing of the parameter was suggested.

This third phase of the study deals with the application of remote sensing to the solution of problems of planning and management of water resource systems.

The objective herein is to devise the means and methods whereby a new data source (remote sensing) may be incorporated into existing operational procedures currently in use by management agencies concerned with hydrologic and water resource systems. Alternatively, the necessity of generating new approaches for the application of remotely sensed data is anticipated for certain functions not adaptable to the new technology.

Progress in this phase is seemingly more deliberate, seeking to find applications where most rapid implementation can be affected to demonstrate the utility of the technology.

3.2 WORK PERFORMED DURING PERIOD COVERED BY THIS REPORT

Three areas of hydrologic applications have been defined for this period, scoped to be compatible with other efforts in connection with the Earth Resources Technology Satellite research concurrently under study by this project team.

Availability of the multilevel data platforms afforded by low-flight aircraft, with ground measurements made concurrently; high-flight imagery (U-2) both pre- and post-ERTS launch; and the multispectral 4 channels scanner imagery produced by ERTS-1, on a repetitive 18-day cycle permiting some comparative assessment.

This data is acquired for a series of specific targets in the Central California Region defined as the Delta Test Site, with some peripheral input from scans made in adjacent areas of high mountains and in the San Francisco Bay Area and North Coastal Region.

Among many possible user needs, which have been considered, several have been selected for initial evaluation. Examples presented are typical operational tasks of water resource managers. These illustrations reflect areas of progress principally because of the concurrent efforts being made by the project team in analysis and utilization of the ERTS-I imagery.

Sample studies include three common to our ERTS-I research work, as well as for proposed skylab application:

1. Gross water quality changes in deltaic regions,

2. Optimization of multiple-use management of large water resource systems,

3. Prediction of snowpack water yields from high mountain regions.

Progress has been made in the first two subjects. Work on snow, which is cooperative with the staff of the FRSL (Berkeley) has been limited pending receipt of winter season data now being acquired and distributed.

3.2.1 Water Quality and Water Resource Systems Application

Significant progress in monitoring certain water quality constituents in both natural and man-made water bodies like lakes, reservoirs and river systems has been made in the initial testing of satellite data capabilities. Three additional levels of image platforms were used in conjunction with the ground truth work to select the image format, define the spectral bands, and to select optimum target sites for various quality conditions.

Figure 3.1 depicts the general area of the investigation and denotes fifteen specific target areas, subject to future amendment. Intensive efforts were made at the site of the confluence of the Sacramento and American Rivers in Sacramento, California and in the Lake Berryessa area.

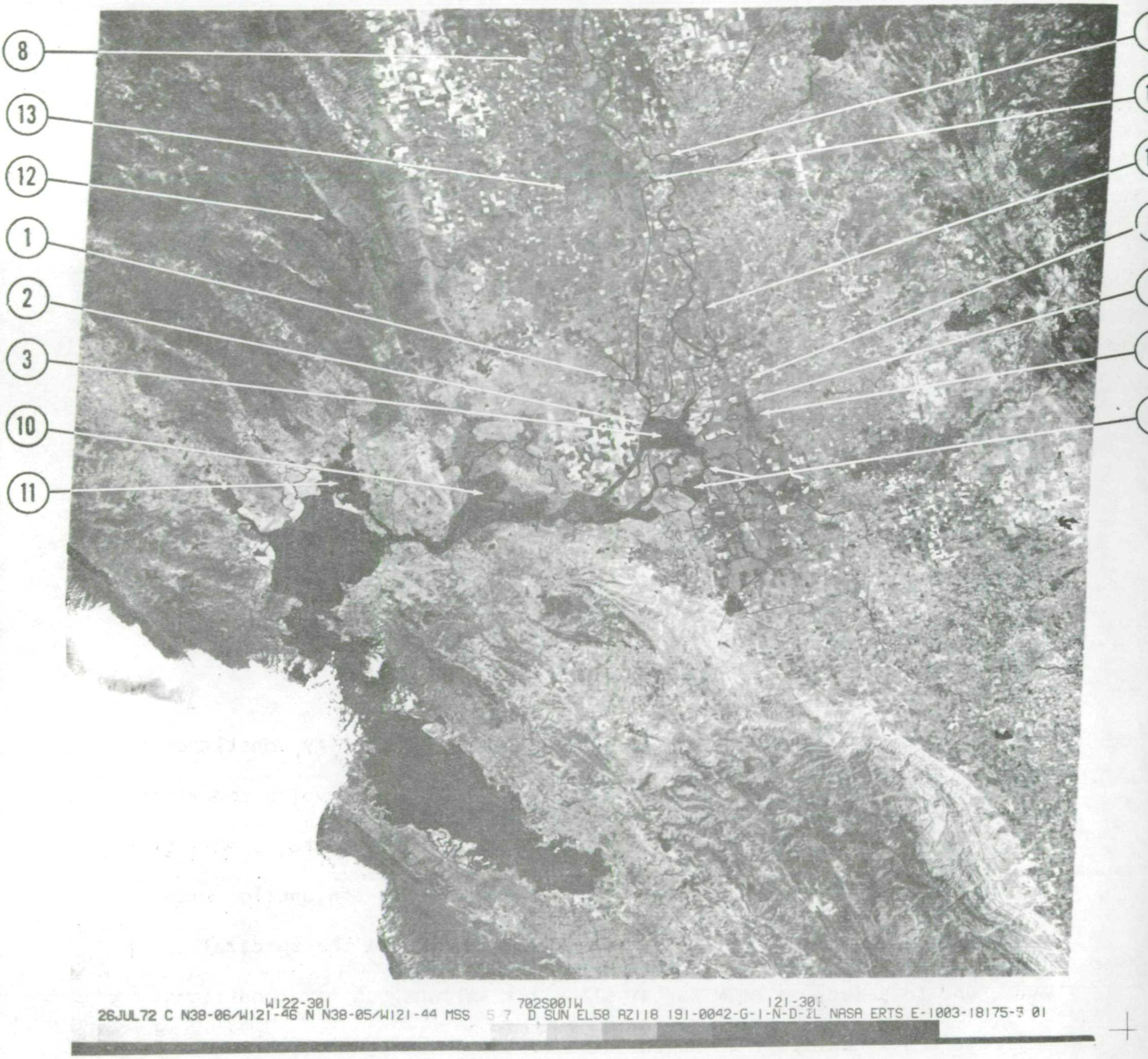

Figure 3.1. Selected study areas in San Francisco Bay and Sacramento-San Joaquin River Delta Test Sites.

Clear Lake and Folsom Lake are also being included in the reservoir systems being monitored. The identification of the numbered sites is presented in Table 3.1.

Discussions have been held with the agencies (local, state and federal) principally responsible for conduct of ongoing water quality field monitoring programs for the sites and tentative arrangements for early access to data acquired have been made.

Agencies include the California Department of Water Resources and the U.S. Bureau of Reclamation who jointly operate the Delta Water Quality Monitoring Program, both in-house and via contracted services. Other local sources for specific areas have been used. Supplementation of these data by project personnel in a regular field measurement program for the primary sites has been made operational on a bi-weekly (or more often) basis consistent with weather phenomena and to verify seasonal changes associated with physical and biological characteristics of the water bodies.

Table 3.2 presents a summary assessment of the water quality and important physical parameters of interest to water resource management as potentially capable of definition by remote sensing.

Table 3.1 Selected Study Areas

Sacramento - San Joaquin River Delta Region, California

1. Lindsey Slough
2. Sacramento River near Rio Vista
3. Andrus Island (Brannan Island)
4. Beaver Slough
5. Hog Slough
6. Sycamore Slough
7. Frank's Tract

Other Sites

8. Colusa Basin Drain into Sacramento River
9. Discovery Park (Confluence of American & Sacramento Rivers at Sacramento)
10. Suisun Bay
11. San Pablo Bay (Salt concentration ponds)
12. Lake Berryessa
13. Davis - Municipal Sewage Stabilization Ponds
14. Lake Washington (Port of Sacramento)
15. Stone Lake

3.2.2 Snowpack and Water Yields

Consultation with the California Department of Water Resources staff on snow measurements and procedures currently in use has produced the format for prediction of water yield from snow in storage. The adaptation of remote sensing data acquisition into this prediction procedure is being studied by graduate students in hydrologic analysis in the Department of Civil Engineering under the direction of this project leader. This work will be completed in the current grant period and will be reported in the forthcoming annual report in May, 1973.

TABLE 3.2 EVALUATION OF SELECTED STUDY AREAS

HYDROLOGIC PARAMETERS	SELECTED STUDY AREAS												
	Lindsey Slough 1	Sacto. R.- Rio Vista 2	Andrus Is. 3	Beaver, Hog Sycamore S. 4,5,6	Frank's Tract 7	Colusa Basin Drain 8	Discovery Park 9	Suisun Bay 10	S.P. Bay Ponds 11	Lake Berryessa 12	Davis Ponds 13	Lake Washington 14	Stone Lake 15
Stream Morphology	X			X		X	X	X					
Surface Velocity & Direction		X		X	X		X	X					
Stream Stage-Discharge	⊗	X		X		X	X						
Turbidity-Suspended Sediment	⊗	⊗	X	X	X	X	X	⊗	X	⊗	X	X	X
Hydrocarbon Surface Films		X	X		X		X	X					
Water Chemistry	⊗	X	X	X	X	X	⊗	X	⊗		X		
Surface Temperature	X	X	X	X	X	X	X	X	X	X	X	X	
Surface Dissolved Oxygen	X	X	X	X	⊗	X	X	X		X	X	X	
Phytoplankton Density	X	X	X	X	⊗	X	X	⊗	X	⊗	⊗	X	⊗
Riparian Vegetation	X	X		⊗	X	X	X	X	X	X	X		
Lake Surface Area					X					X			X
Lake Depth					X					X	X	X	X
Change in Storage			⊗							⊗			X
Watershed Delineation	X			X		⊗				X			X
Watershed Topography	X			X		X				X			X
Vegetation-Type & Coverage	X		X	X		X	X	X		X			X
Land Use	X	X	⊗	X	X	X	X	X	X	X		X	X

X Look for parameter at selected study area

⊗ Important parameter at selected study area

3.3 FUTURE PROPOSED WORK

Continuation of the studies of application of remotely sensed hydrologic data for water resource management and operation is proposed for ongoing research under this NASA Grant.

Imagery provided by the several instrument platforms now operating is yielding the basic information which may be applied to a variety of user tasks. The interpretation, enhancement and utilization of much of the satellite data now being collected will continue to be directly useful for such application. Substantial time lag is inherent in the processes now used to collect, process and distribute imagery from all the sources. Thus, the information acquired late in the life of ERTS-I and the complementary high-flight programs will first become available at the investigator level mid-way of the following year, that is, in late 1973.

A very high potential for effectively enhancing satellite imagery for water resource application is being demonstrated by fellow researchers in this project. The techniques which have been devised give the capability for greatly extending the use of remotely sensed data in both hydrologic work, water quality assessment and in management.

Sequential coverage with multispectral images over time spans of more than one season are expected to permit a wider range of verification of potential uses. Additionally, the multilevel data provided by the current programs will benefit the analysis.

Recent periods of discussion and consultation with several direct user groups suggests that analysis and testing of applicability of remote sensing on real time problems will serve a dual purpose of demonstrating the utility of this technology in a very practical way and will further

permit a significant opportunity to work with the user group in a combined developmental and training mode. Since future users must be trained to recognize the potential capability of remote sensing technology and to seek new applications within their areas of specialization, this approach is proposed as an expedient to those ends. Cooperation of user teams is assured and interest is great on the subjects currently under study. Other remote sensing applications are being explored and, as noted previously, the use of enhancement techniques will clearly permit supplemental uses of the data beyond those presently recognized.

In summary, it is proposed to continue this investigation on the application of remote sensing to hydrologic and water resource management tasks in a direct cooperative mode with selected user groups of interest, who will make available ground truth information from present sources. Imagery currently available will be used intensively and additional sources may be added when available.

Chapter 4

REMOTE SENSING DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA

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4.1 INTRODUCTION

During this funding period, two major studies are being carried out in northern California, namely:

1. Measurement of hydrologic resource parameters through the use of spacecraft and aircraft data in the Feather River Watershed area (see Figure 4.1).

2. Analysis of the Northern Coastal Zone Environment with the aid of spacecraft and aircraft data (see Figure 4.2).

An explanation of the study objectives and the relationships between these objectives and certain previous studies can be found in Chapter 4 of the 1971 and 1972 Annual Progress Reports for the Integrated Study. The following introductory text provides brief background information for each of the studies and defines the approach being used by the Forestry Remote Sensing Laboratory. Recent developments with respect to image analysis, particularly in the area of automatic image classification and data processing, are emphasized.

The body of this chapter is divided into two parts -- one for each of the studies listed above. Specific study objectives, work performed

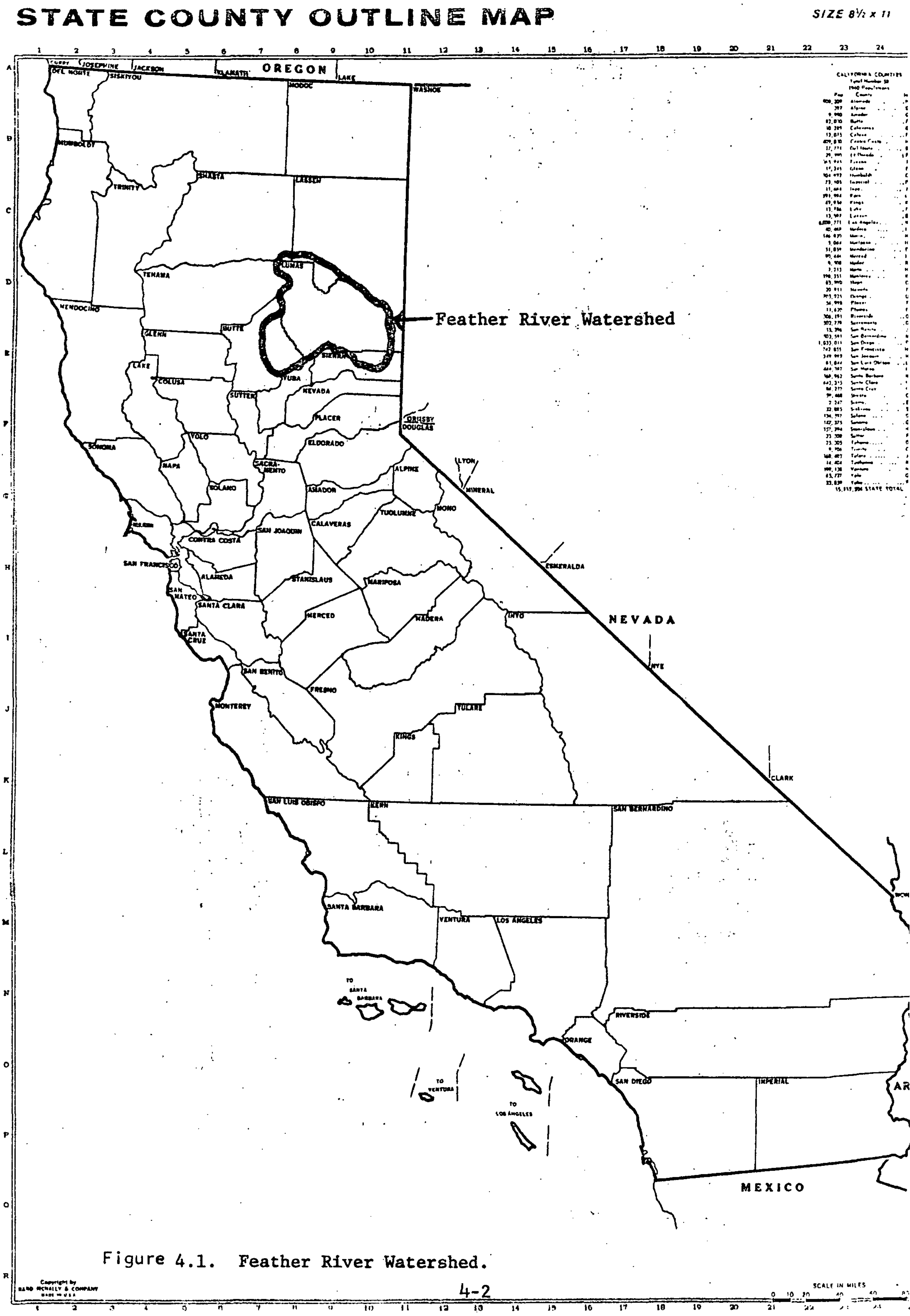


Figure 4.1. Feather River Watershed.

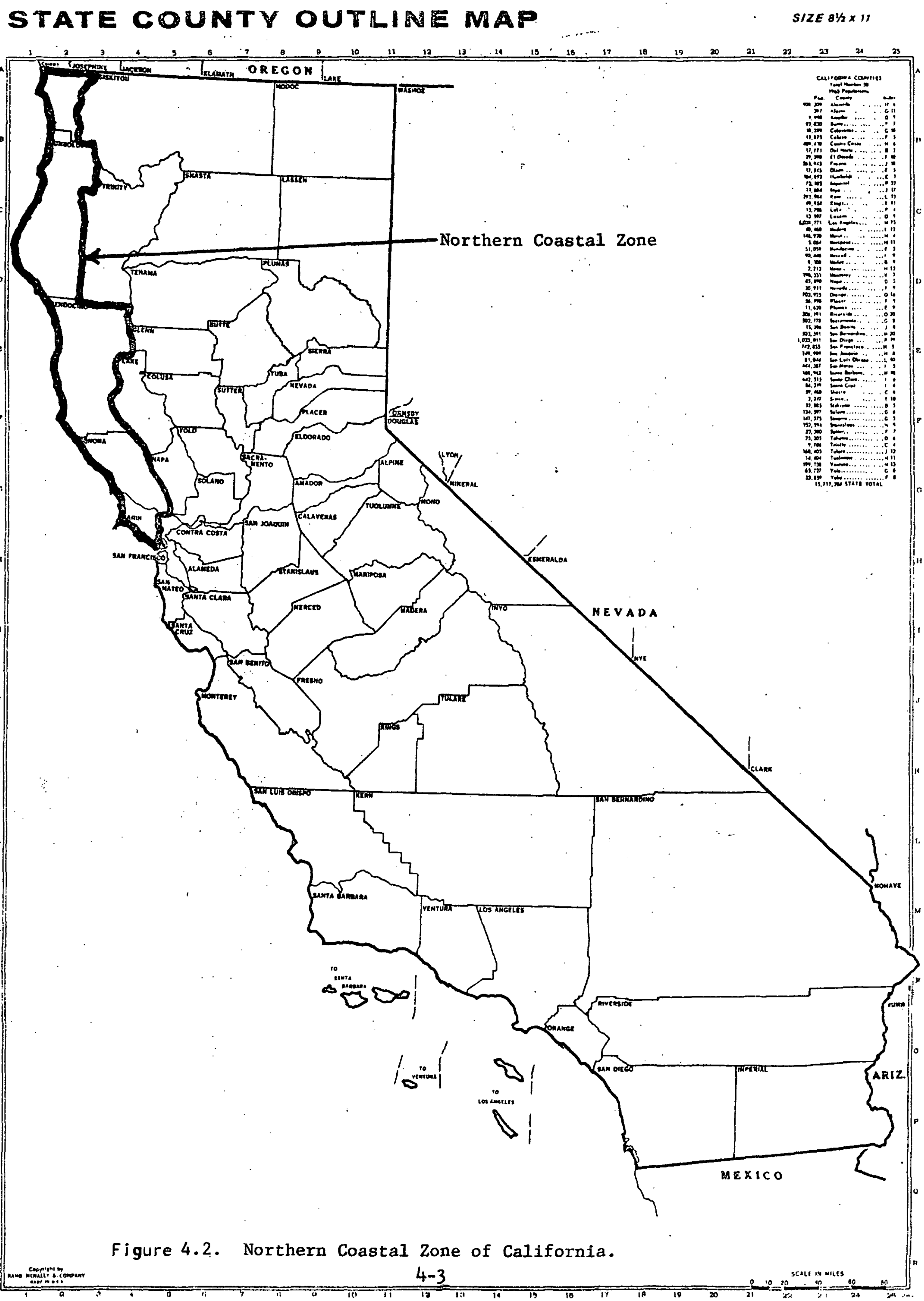


Figure 4.2. Northern Coastal Zone of California.

during this past funding period and future proposed work are documented.

4.1.1 Background

The Feather River Watershed and the Northern Coastal Zone areas possess a number of characteristics which enhance their value as test sites for this integrated study.

The California State Water Project is one of the most extensive and ambitious water resource developments ever attempted. The source of water for this vast project is the Feather River headwaters region, which drains into Lake Oroville, the keystone of the project in terms of flood control and regulation of downstream water delivery. Thus, the Feather River is an important component of an actual resource development operation. As such, conclusions which are reached regarding the utility of remote sensing data can be evaluated not only on a purely theoretical basis, but also on decisions that have been made, and in comparison to conventional techniques which have been and are being used to gather needed data. In addition to its importance in the California Water Project, the Feather River area contains an extensive system of hydroelectric reservoirs which are operated by a public utility company in conjunction with the state water project facilities.

Most of the actual watershed lands of the Feather River region are administered by the U.S. Forest Service, which is charged with the responsibility of multiple-use management of the resources of the area. Although water storage and power-generation facilities have been highly developed, in many cases the management of the actual watershed lands themselves (to provide an optimum mix of resources including wood, livestock forage, recreational opportunities, fish and wildlife, and water)

is not currently highly advanced. This is due primarily to an incomplete understanding of the complex man-resource interaction, and a lack of basic data regarding the physical parameters of the vast, wild, and poorly accessible areas involved. Thus, an opportunity exists not only to compare remote sensing techniques against conventional methods of data acquisition, but in many cases to evaluate the potential for providing information that is currently unavailable in the form or with the degree of accuracy, necessary to permit the development of a highly sophisticated broad-scale resource management system.

Likewise, it is becoming increasingly apparent that the Northern Coastal Zone of California is in itself an important resource. As population increases, the coastal zone will come under mounting pressure for development, both as a place of human habitation and as a place for more intensive use and development of natural resources. From San Francisco southward, the coast is already the site of numerous urban centers, and the problem of planning entails not only how to plan for future development, but also how to deal with currently existing development. In many ways the northern coastal region presents somewhat different problems. In general the north coast (consisting of the counties of Marin, Sonoma, Mendocino, Humboldt, and Del Norte) is relatively rural, with an economy based on agriculture, timber, commercial fishing, and tourism. However, it is expected that intensive resource use resulting from increasing population will soon become a serious problem unless wise land use planning is undertaken. Thus the north coastal zone presents an excellent opportunity for intelligent, informed planning of development before intensive land use activities become widespread.

One prerequisite of intelligent land use planning of any region is a detailed and comprehensive knowledge as to the environment of the area in terms of its effect on potential resource management and use. In the north coastal area, one urgently needed type of information is an integrated inventory and evaluation of the physical characteristics of the region as they relate to the suitability for various types of land use. Since the bulk of the region can be classified as essentially wild land, it is particularly well suited to investigations of the ways in which remote sensing and other supporting data may be used in conducting such potential land use evaluations.

4.1.2 Approach

Our experience to date has convinced us of the necessity to use a systems concept and team approach in solving problems of interest to the earth resource manager. Consequently, the Forestry Remote Sensing Laboratory has been organized to include five functional units (see Figure 4.3). These units address themselves to the most important problems which must be solved if a remote sensing system is to be employed successfully for earth resources inventory purposes. The five problem areas investigated under this team approach are as follows:

1. Determination of the feasibility of providing the resource manager with operationally useful information through the use of remote sensing techniques;

2. Definition of the spectral characteristics of earth resources and the optimum procedures for calibrating multispectral remote sensing data acquired of those resources;

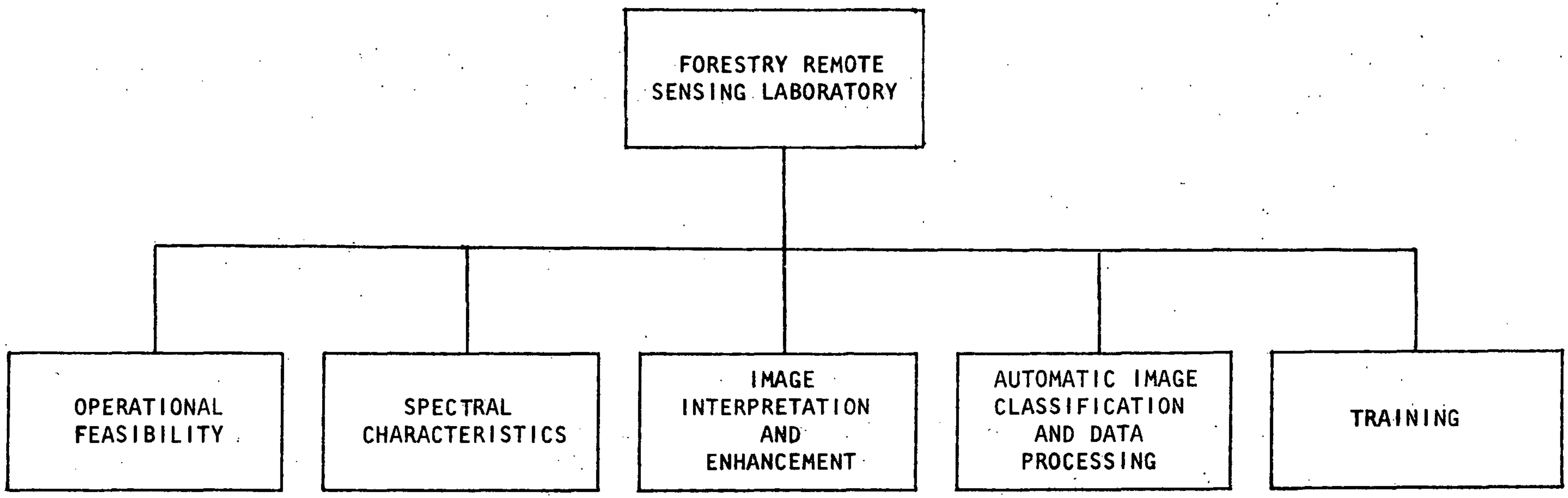


Figure 4.3. Organizational diagram of the Forestry Remote Sensing Laboratory, University of California, Berkeley, California.

3. Determination of the extent to which humans can extract useful earth resource information through a study of remote sensing imagery either in its original form or when enhanced by various means;

4. Determination of the extent to which automatic data handling and processing equipment can extract useful earth resources information from remote sensing data; and

5. Effective dissemination of remote sensing results through the offering of various kinds of training programs in which the interaction between users and scientists can be emphasized.

Since the Operational Feasibility Unit, Image Interpretation and Enhancement Unit and the Automatic Image Classification and Data Processing Unit were the most active Units on the Integrated Project, the following parts of the introductory section are devoted, respectively, to the procedures used by these Units.

4.1.2.1 Operational Feasibility Unit

Initial efforts of this Unit have been directed towards further defining those specific types of information which are required by potential user agencies and individuals within the test areas. Specifically, this phase of work has entailed an extensive literature review and discussions with persons currently involved in gathering resource data. An attempt has been made to determine the methods currently used, costs and amount of effort involved, and their accuracy and timing. In addition, evaluations have been made of current methods in regard to ways in which they could be improved in terms of economy, speed and accuracy so as to better serve those utilizing the information. Based on these findings, recommendations are being made as to the details of the surveys which are the subject of

investigations carried out by the technical units of our laboratory.

During the testing phases of each experiment, cooperative work is carried out with the technical units to ensure that the format of information extracted from the remote sensing data and the testing procedures are such that an adequate evaluation can be made of the results based on actual operational information needs. This involves, where necessary, the development of pertinent quantitative testing procedures which provide statistically reliable results.

The results of these quantitative tests are objectively evaluated in light of the user needs described above. Conclusions are drawn as to the apparent value of remote sensing data in satisfying these needs. In addition, an attempt is made to specify those interpretation and handling techniques, information formats, and complementary uses of ground data which will optimize the usefulness of remote sensing data. Finally, conclusions are drawn as to future procedures to be followed which would lead to the optimum use of remote sensing data-gathering techniques for operational surveys.

4.1.2.2 Image Interpretation and Enhancement Unit

Personnel of the Image Interpretation and Enhancement Unit are working with ERTS-1, high flight and ground data to develop a methodology for extracting by means of manual image interpretation resource information useful to the California resource specialist. Optimum methods for selecting and training image interpreters, performing interpretation tasks, and compiling and evaluating interpretation results are being demonstrated. Among the "end products" of this research are map sheet overlays, tabulated statistical data, and a summary evaluation of the usefulness of remote

sensing data for making rapid and accurate resource surveys.

Preparation of Imagery. Interpretation is being performed on a variety of products, ranging from a direct use of black-and-white photo products to various multiband and/or multidate color combined and enhanced images. These color enhanced images are produced using the FRSL optical combiner, by means of direct color photo compositing, through a diazo color image combination process, or using the FRSL color TV system which electronically combines digital tape or hard copy photo data.

Collection of Ground Data. All data gathered (1) on the ground, (2) from low flying aircraft, and (3) from high flight photography are combined with additional information collected within the study areas by user agency personnel and are effectively used when image interpretation results are quantitatively evaluated.

Selection of Image Interpreters. To maximize the amount of information extracted from remote sensing data, the image interpreters chosen to perform interpretation tasks are selected on the basis of displaying a high degree of visual and mental acuity. Quantitative tests performed at the FRSL have indicated that individuals with good color perception, having extensive experience and training in remote sensing, and possessing a high degree of personal motivation significantly out-perform those lacking any or all of these qualities.

Training Image Interpreters. Reference materials needed to train image interpreters as to the identifying characteristics of each important resource type or condition being surveyed are being prepared (i.e., P.I. keys, maps, charts, statistical data, word descriptions, schematic drawings,

etc.). All reference materials previously prepared by our group of the NASA test sites in California are being employed. Low altitude oblique photography is also being used as input to the training materials.

Performing Image Interpretation Tasks. The specific image interpretation tasks being performed during this Integrated Project are described in the following sections of this Chapter. It should be emphasized, however, that a series of quantitative interpretation tests are being performed with a group of highly skilled photo interpreters using ground data and selected frames of multiband, multidate, and multiband/multidate imagery, some of which has been color enhanced with the FRSL optical and electronic systems. Interpretation test results are statistically analyzed to determine which image types provide the maximum amount of resource information. On the basis of these quantitative tests, supported with analyses of densitometric measurements, imagery deemed optimum for making resource surveys is selected.

Compilation and Evaluation of End Products. All ground truth data collected, plus information derived from low altitude oblique or vertical aerial photos is used to evaluate interpretation results. Specifically, all interpretation results are subjected to quantitative evaluations with respect to accuracy of boundary placement, accuracy of identification, and degree of identification efficiency. To accomplish this, both direct and indirect methods are employed which have been proven applicable in previous studies, and which guarantee that a measure of statistical reliability can be associated with each conclusion.

Results actually achieved during the present reporting period through

use of the procedures described above will be found in later sections of this report.

4.1.2.3 Automatic Image Classification and Data Processing Unit

During the period covered by this report, considerable effort has been directed toward developing a capability for efficiently handling digital ERTS data, and integrating software with hardware into an operational system.

The approach to hardware acquisition to date has been motivated by the need to consider resource analysis using telemetered data as well as "hard-copy" reproductions from proposed satellite image systems. In the process of preparing for ERTS and SKYLAB imagery, the FRSL has developed a computer system which has local preprocessing and display capabilities as well as a data link to high speed, high capacity digital computers on the University of California campus. The types of large scale computers which are available for use include: a CDC 6400, a CDC 6600 and a CDC 7600. Standard peripherals such as line printers and X-Y plotters are also available. The FRSL computer display system, diagramed in Figure 4.4, consists of the following hardware components:

a. digital computer
b. interactive color display
c. high resolution black-and-white graphics CRT
d. digital disc memory
e. digital 9-track tape transports
f. digital cassette recorder
g. high speed paper tape reader/punch

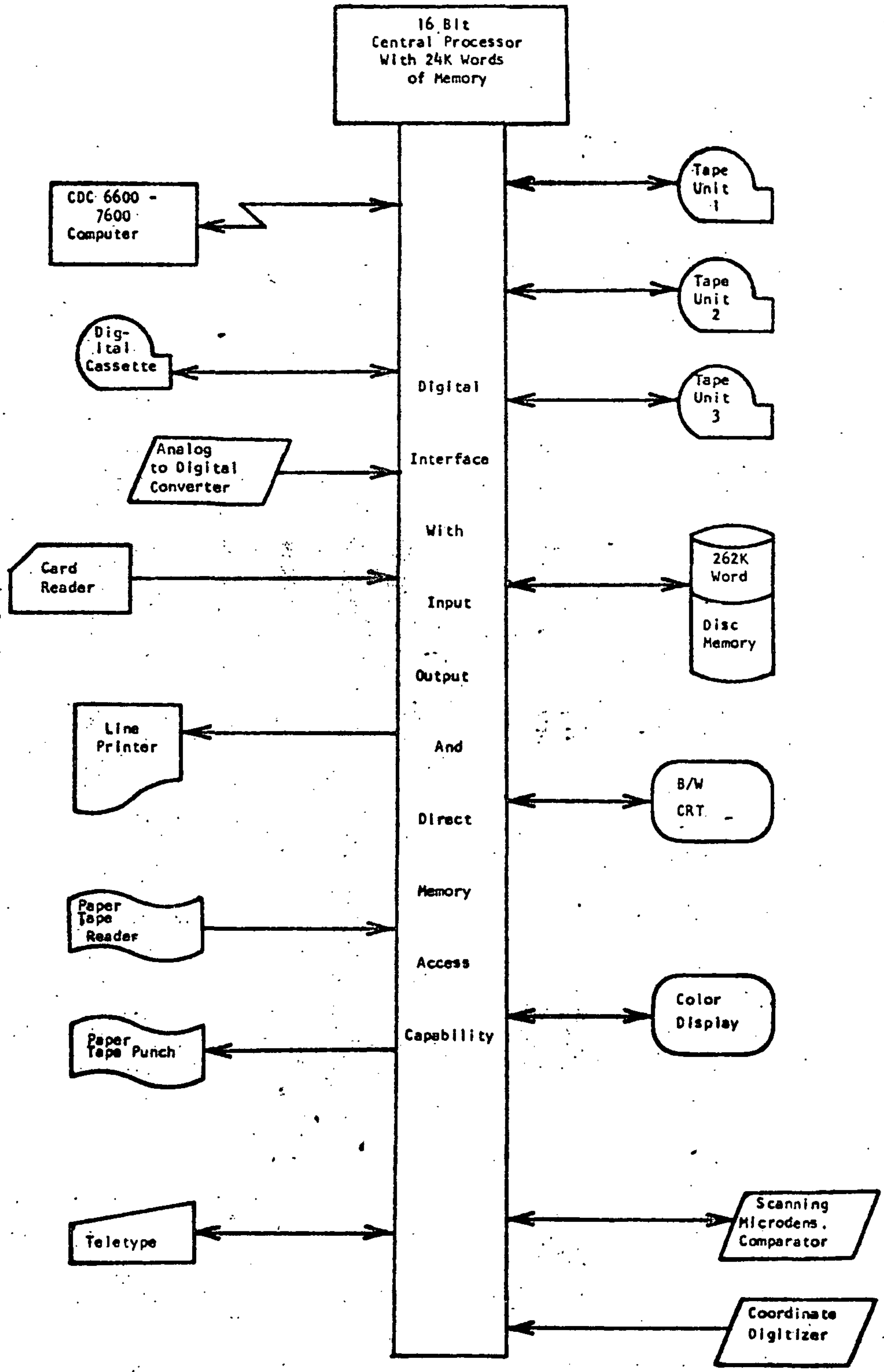


Figure 4.4. The Forestry Remote Sensing Laboratory computer display system.

h. card reader

i. line printer

j. coordinate digitizer

k. custom scanning microdensitometer/comparator

l. high speed data link to large scale computers

m. A/D converter

Four major classes of computer programs have been assembled for use on the FRSL computer and the associated large scale computers: (1) Digital image handling and display, (2) Statistical spatial and spectral pattern recognition, (3) General statistical, and (4) Multilevel data bank. These programs are being used to process the data obtained from ERTS-1, aircraft, and ground data collection. Their use allows the selection and reformatting of selected areas of the state that are being analyzed intensively for correlation with ground data, mapping of features of interest based on their spatial and spectral characteristics, selection of optimum dates and spectral band(s) for classification, and comparison with existing data, both mapped and point. They are also being used to compare manually mapped boundaries and computer generated boundaries with ground data.

Figure 4.5 depicts the various software components that have been linked together to provide a system for the processing of remote sensing data, and specifically of ERTS and SKYLAB data. Each of the steps depicted in the flow chart is described in detail below.

1. <u>Reformat ERTS Tapes and Generate Tape Mosaic</u>

Before the ERTS digital tapes can be used efficiently they must be reformatted. This is done on the FRSL computer to minimize computing

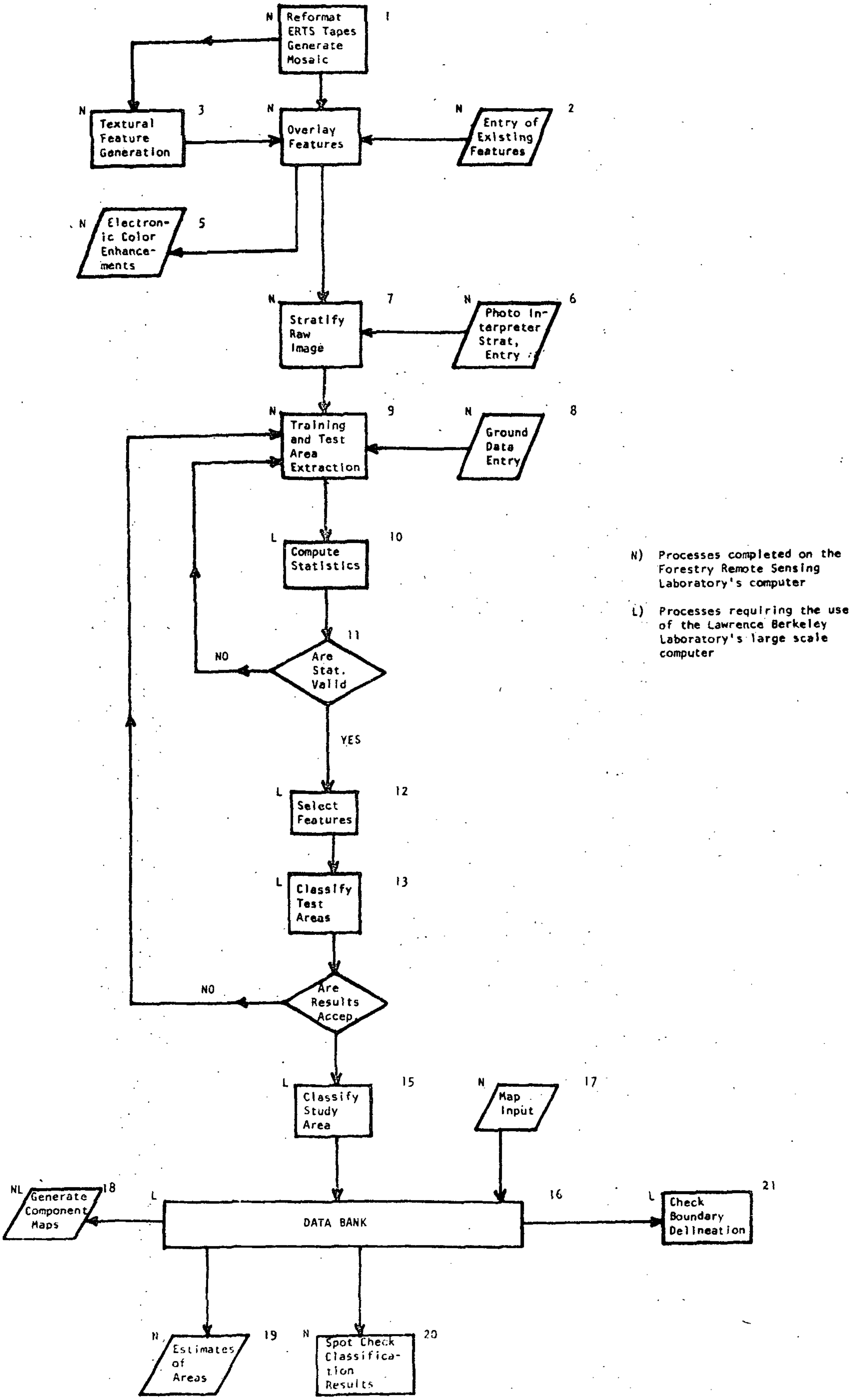


Figure 4.5. The Forestry Remote Sensing Laboratory computer software system.

cost and allow human interaction. At this point the tapes necessary to cover intensive study areas are selected, and those portions of tapes not needed are eliminated. Coordinate information is placed in a library to be used in later stages of the processing.

2. Entry of Existing Features

Information such as topography and rainfall, and data from other imagery sources may be entered if they will aid in the discrimination of the classes of interest. They can be entered manually with digitizing equipment, automatically through the scanning microdensitometer, or from existing digital tape data.

3. Textural Feature Generation

Software is being developed to quantify the spatial frequency characteristic of the area surrounding a given picture element. This step will be used only when the spectral data are insufficient or when the spatial information is more cost effective.

4. Overlay Features

The images of features coming from steps 1 - 3 are put in common register and written on magnetic tape in the format used by the display and classification programs in later steps.

5. Enhancement and Display

The FRSL computer display is used to combine features and transform the data to increase the apparent information content. Current enhancement programs include multiband false color which can be generated from ratio, differentials, nonlinear transforms and density slicing. These procedures allow easier photo interpreter discrimination of edges, tones

and textures of classes of itnerest.

6. Photo Interpreter Stratification Entry

Because of the human ability to recognize and delineate boundaries between general land classes and to further break these classes down by their textural and tonal characteristics, this step has been provided to allow the incorporation of such data into the automatic classification process. The strata data can be entered through the coordinate digitizer by the interpreter at the time of delineation (to minimize the effort required to get the data into the system) or by an operator at a later time.

7. Stratification of Raw Image

The data entered by the photo interpreter from step 6 are put in the common register with the multifeature images from step 4. This will allow the automatic classification to be within individual strata or logical combinations of strata. Preliminary results from ERTS-1 indicate that this stratification increases the accuracy of the resultant combined classification significantly and reduces the computing cost by eliminating large areas that do not need the detailed classification provided by the automatic classifier.

8. Ground Data Entry

Through the use of the display/light pen, coordinate digitizer, and photo comparator, information obtained from ground visits, high flight photography and low altitude photography is entered. This information is used at several points to train the classifier and to check classification results.

9. Training and Test Area Extraction

Ground data are used to extract selected training and test areas from the raw stratified images that have been created through previous processing steps. If further in the processing it is found that the training is inaccurate or inadequate, processing returns to this point to allow retraining of the classifier.

10. Compute Statistics

Raw data from the training areas are reduced to the statistic necessary to determine the separability of the classes, select the features to be used in the classifier, and generate the discriminant function in the classifier.

11. Are Statistics Valid?

Statistics generated in the previous step are used to check the validity of the training set. If the data statistics seem adequate the processing is continued, otherwise the control is returned to step 9 where new training areas are defined to eliminate the errors in the original set.

12. Feature Selection

Once the training set has been defined the optimum set of features is selected for use in the discriminant function. Because of the geometric increase in cost of adding features to the discriminant analyzer and the need to satisfy the requirement of the user, the choice of the number and types of features is very critical to the cost effectiveness of the system.

13. Classify Test Areas

Features and statistics from the previous steps are applied to intensive test areas and a point by point maximum likelihood discrimination is

made. Thresholds can be applied to minimize the incorrect classification of features not represented in the training set. A second level of classification can be performed by applying an algorithm that uses the results of the point by point classification and the spatial relationship of neighboring points to assign a final class to each point. This is used to reduce classification errors that are due to points that fall on field boundaries in agricultural areas or between vegetation types in the wildland areas.

14. Are the Results Acceptable?

Using ground data, the results of the point by point classification are checked on an area by area basis either manually or automatically by overlaying the digitized coordinates of the field boundaries from the high flight photography on the output of the classifier, and applying the ground data to these fields. The summarized data are checked to determine whether the results of the classification meet the requirements of the user. If not, processing is returned to step 9 for further training.

15. Classify Study Area

After the intensive test areas have been classified and the statistics have been accepted, the entire study area is classified. This can be done using every point, or by using some sampling scheme to reduce the total number of points to be analyzed. The sampling scheme is determined by the sizes of the fields in the study area in relation to the sensor resolution, and the accuracy desired.

16. Data Bank

A system of programs is used for the storage and retrieval of the

various types of mapped information that have been generated. The system allows the overlaying of selected maps and the performance of logical operations to produce an output map that is a composite of the input maps and which reflects the constraints specified by the user.

17. Map Input

Using the comparator capability of the scanner and the coordinate digitizer, mapped data such as soil type, land ownership, and topography are entered through the FRSL computer facility into the data bank.

18. Generate Composite Maps

Several output devices are available to produce a wide variety of maps from the data bank. The color CRT is used to generate color representations of the classification results. Computer controlled plotters are used to generate line drawings that can represent mapped features to any specified scale. The high resolution CRT can also be used to generate line drawings to predetermined scales. Where grided information is to be displayed, the line printer is often used because of the inherent grid generated by the printer and the discrete representation of classes with the characters.

19. Estimates of Areas

Using the data bank and summary routines, estimates of areas in each class and their locations can be produced. Through statistical routines, corrections in estimates can be made. These corrections are generated early in the processing using intensive test area data.

20. Spot Check Classification Results

In cases where high accuracy is desired, spot checks of the results may be made outside the intensive test sites to account for geographic

variability in feature characteristics.

21. Check Boundary Delineations

When two or more methods or data bases have been used to map the same parameter it may be necessary to check and display the differences that occur between the maps. The output of these routines may be a display of errors in mapping or may provide a change detection capability when multi-date data are used as input.

4.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

4.2.1 Analysis Within the Feather River Watershed

4.2.1.1 Introduction

Work within the 2.5 million acre Feather River Watershed region is centered on two topics -- vegetation/terrain analysis and snow surveys. Table 4.1 lists several of the user agency groups which are keenly interested in the results of this research.

The approach to wildland vegetation/terrain resource analysis emphasizes the following broad objectives: (1) the development of interpretation aids and related resource descriptors, (2) the quantitative testing of manual interpretation procedures in the detection and classification of landscape elements, (3) the determination of cost-time factors relating to interpretation and mapping resources using various interpretation techniques, and (4) the acquisition of ground control data.

Manual interpretation procedures used in this experiment are dependent on the interpretation aids and techniques developed. The making of analyses of interpreter efficiency and the achieving of high accuracy of interpretation results are the main objectives of the work being done at the Davis

TABLE 4.1 USER AGENCY COOPERATION
WILDLANDS RESEARCH APPLICATIONS PROJECTS

USER GROUP AGENCY	PERSONNEL CONTACTS	REMOTE SENSING RESEARCH APPLICATION
CALIFORNIA REGION FRAMEWORK STUDY COMMISSION FOR SOUTHWEST INTER-AGENCY COMMITTEE: WATER RESOURCES COUNCIL	MR. JIM COOK (USFS) MR. LYLE KLUBBEN (USFS) MR. WILLIAM FRANK	REGIONAL VEGETATION/TERRAIN MAPPING LAND USE PRACTICES AND CHANGES LANDSLIDE AND STREAM SEDIMENTATION DETECTION
REDWOODS NATIONAL PARK, U.S. NATIONAL PARK SERVICE	MR. H. T. HATZIMANOLIS RESOURCES MANAGEMENT SPECIALIST	CHANGE DETECTION ANALYSIS LAND USE PATTERNS ON ADJACENT LANDS VEGETATION INVENTORY REGENERATION ANALYSIS
DEPARTMENT OF WATER RESOURCES, STATE OF CALIFORNIA	MR. G. SAWYER MR. A. DE RUTTE	SNOWPACK DETECTION HYDROLOGIC OUTPUT PREDICTIONS
CALIFORNIA COOPERATIVE SNOW SURVEY	MR. V. LEMMONS	SNOWPACK DETECTION AND HYDROLOGIC PREDICTIONS
CALIFORNIA DEPARTMENT OF CONSERVATION DIVISION OF FORESTRY	MR. T. ARVOLA MR. C. PHILLIPS	VEGETATION-SOILS INVENTORY FIRE DAMAGE APPRAISAL RANGELAND CONTROL BURNING MONITORING COMPLIANCE WITH FOREST PRACTICE ACT
U.S. FOREST SERVICE	MR. JIM MC LAUGHLIN	SOILS-TERRAIN ANALYSES
TAHOE REGIONAL PLANNING AGENCY	MR. JIM BRUNER	ENVIRONMENTAL CHANGE DETECTION SEDIMENT POLLUTION ANALYSIS LAND USE INVENTORY
CALIFORNIA STATE DEPARTMENT OF PARKS AND RECREATION	MR. GEORGE RACKELMANN MR. JOHN HAYNES MR. SANDY RABINOWITCH MR. KEN COLLIER MR. ED POPE	LANSCAPE INVENTORY SITE LOCATION AND PLANNING

Lake intensive site. Consequently, the results of these evaluations are indicators of the validity of the interpretation aids and procedures used.

With respect to snow surveys in the Feather River region, section 228 of the California Water Code states that the Department of Water Resources will gather snow data, through the California Cooperative Snow Survey Program, in order to forecast seasonal water supplies. Many county, state and federal agencies and private organizations participate in this program and obtain snow data by standard snow survey methods on established courses. However, for the entire 2.5 million acre Feather River Watershed region, snow data are collected at only 25 point locations from which water inflow forecasts are made for the Oroville Reservoir facility. Consequently, the long range goal of the snow survey work being conducted by the FRSL is to provide improved means for estimating annual extent of snow cover during critical periods of the melt season. These data, if proven to be valid, could be used to improve the effectiveness of existing stream flow forecasting models.

4.2.1.2 Interpretation of High Altitude Aircraft Color Infrared (CIR) Photography

More than 60 percent of the Feather River drainage basin has been mapped to date utilizing high altitude aircraft CIR imagery. Approximately thirty wildland resource entities among seven landscape categories are being classified (see Table 4.2). A ground controlled vegetation/terrain resource map (see Figure 4.6) has been produced using this classification scheme. Major landscape categories include (1) coniferous forests, (2) hardwood forests, (3) chaparral, (4) grassland-meadow marshland complex, (5) agricultural

TABLE 4.2. CLASSIFICATION SCHEME FOR VEGETATION/TERRAIN RESOURCES WITHIN THE FEATHER RIVER WATERSHED REGION

FOREST RESOURCES

Coniferous Forests

A. High Elevation Red Fir Forest
B. Westside Intermediate Mountain Conifer
BB. Eastside Intermediate Mountain Mixed Conifer
C. Eastside Intermediate Pine-Scrub Forest
D. Eastside Northern Juniper Woodland
E. Eastside Timberland-Chaparral Complex

Hardwood Forests

F. Intermediate Mountain Xeric Hardwoods
G. Westside Foothill Pine-Oak Woodland
GG. Westside Foothill Oak Woodland-Grass
GC. Westside Foothill Oak Woodland-Chaparral
GGC. Westside Foothill Oak Woodland-Grass-Chaparral
H. Mixed Mesic Hardwood Communities
I. Westside Foothill Mixed Hardwood-Conifer Forest

NON-FOREST RESOURCES

Chaparral

J. Westside Valley Front Foothill Chaparral
K. Westside Intermediate Mountain Chaparral
KK. Eastside Intermediate Mountain Chaparral
L. Eastside Valley and Basin Front Sagebrush Scrub

Grassland-Meadow-Marshland Complex

M. Subalpine Grassland
N. Intermediate Interior Valley Xeric Grassland
O. Mesic Meadow Complex
P. Freshwater Marshland

AGRICULTURAL AND RANGELAND RESOURCES

Q. Mesic Cultivated Croplands
R. Mesic Rangeland
S. Xeric Eastside Grassland-Scrub Rangeland

OTHER LANDSCAPE FEATURES

T. Forest Plantation Sites
U. Urban-Residential-Commercial Sites
V. Exposed Soil
W. Exposed Bedrock

- WB. Basalt
- WA. Andesite
- WR. Rhyolite
- WP. Pyroclastics
- WG. Granite
- WU. Ultrabasics
- WS. Sedimentary
- WM. Metavolcanics

HYDROLOGIC RESOURCES

X. Standing Water
Y. Running Water
Z. Snowpack

VEGETATION-TERRAIN RESOURCES PERCENT COMPOSITION RANGE WITHIN HOMOGENEOUS DELINEATED AREAS

PERCENT COMPOSITION	CODE NUMBER
0 - 5	1
6 - 20	2
21 - 40	3
41 - 60	4
61 - 80	5
81 - 100	6

Figure 4.6. Classification of wildland resources with the Davis Lake intensive study area. Resource classification code numbers refer to percent composition of specific resources within delineated areas. The interpretation was accomplished using high altitude (1:120,000) false-color infrared transparencies. This map functions as ground controlled data, useful in ERTS-1 image analysis, and represents "state of the art" regional mapping. The area represented above is 403,000 acres, about one-sixth the entire Feather River Watershed.

and rangeland resources, (6) other landscape features and (7) hydrologic resources. Elements within these categories have been classified by percentage composition within homogeneously delineated type-areas where uniform color, tone, texture, vegetation density and/or composition are apparent on the imagery. Homogeneous areas were first delineated within effective areas on acetate overlays on each of 60 individual CIR high altitude images.

In addition to this ground controlled vegetation/terrain resource map, the following additional regional resource related maps have been either prepared or acquired: (1) Lithologic Geology, (2) Mean Annual Precipitation, (3) Soil Series Complexes, (4) Elevational Zones, (5) Drainage Network (Strahler Stream Order System) and (6) an available vegetal cover type map (see Figure 4.7). This vegetal cover type map, prepared by the Comprehensive Framework Study California Region, is a portion of a larger map of the Sacramento Basin Subregion, and represents previous "state-of-the-art" regional mapping. It was prepared from reference materials dating back from 30 years ago to more recently. The map is vastly generalized and of questionable validity when compared with ground observations. It by no means equates with the high level of information content obtainable from high altitude CIR photography.

4.2.1.3 ERTS-1 Regional Imagery Analysis

Regional resource interpretation on ERTS-1 imagery have concentrated on evaluating the Multispectral Scanner System (MSS). The following MSS single bands have been investigated for gross informational content: green, no. 4 (0.5-0.6 μm), red, no. 5 (0.6-0.7 μm), infrared, no. 7 (0.8-1.1 μm)

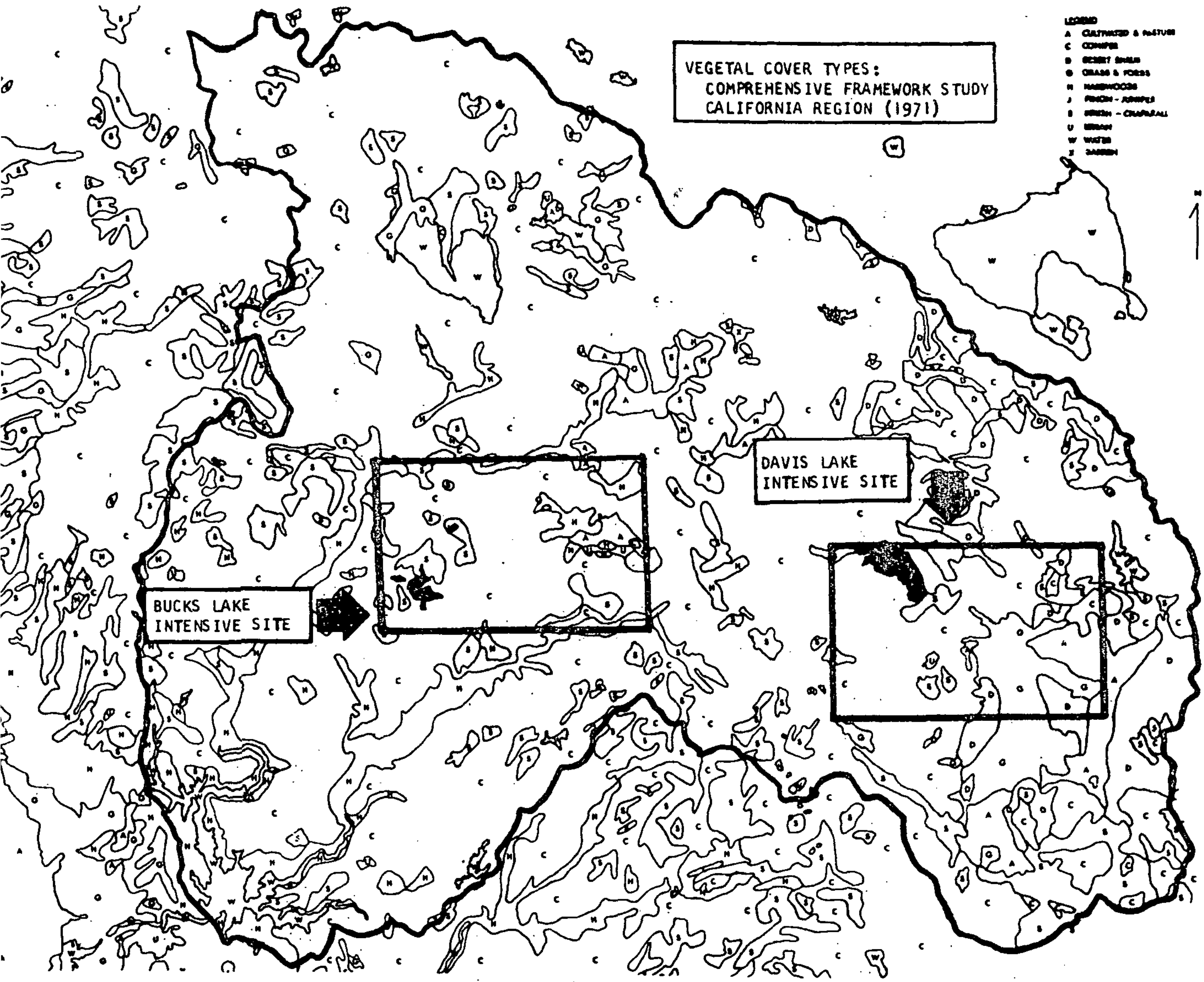
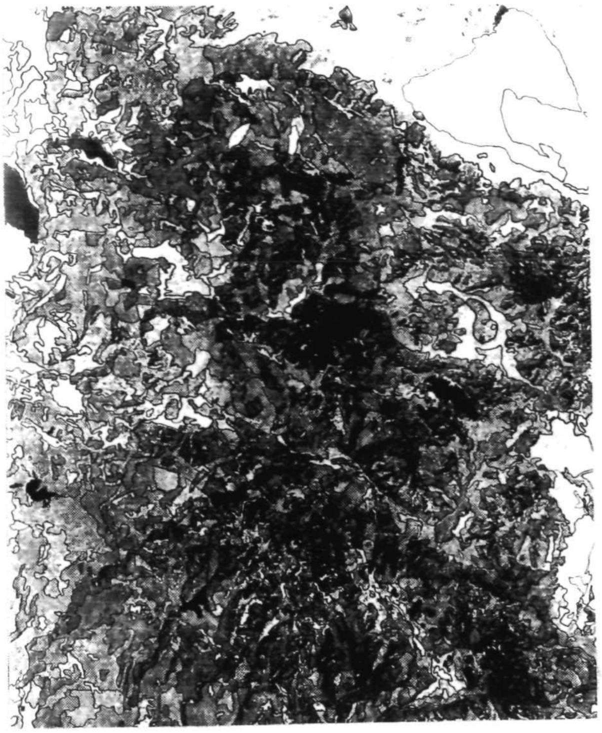


Figure 4.7. This modified version of the vegetal cover type map, prepared by the Comprehensive Framework Study, California Region represents previous "state-of-the-art" regional mapping. Within the Davis Lake intensive study area, the gross generality of resource information is apparent. Figure 4.6 illustrates current "state-of-the-art" resource mapping using high altitude false-color infrared imagery.

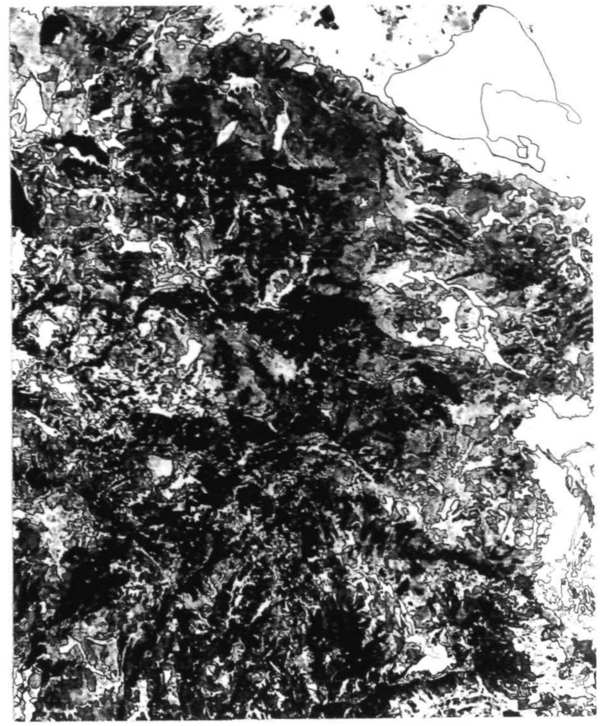
and the false-color composite MSS 4-5-7 NASA/GSFC image. Original 1:1,000,000 single band, single date (July 25, 1970) black-and-white transparency images were professionally enlarged to a 16 x 20 inch print format, approximating the ground control map-scale of 1:250,000. The color combined MSS image used in this initial evaluation was a third generation copy enlargement (16 x 16 inch) derived from an available 9 x 9 color print of the region. Homogeneously appearing areas were delineated on overlays of these four enlarged images (see Figure 4.8) by two trained photo interpreters.

Evaluations of these delineations on each MSS single band and the color-combined image, were accomplished by direct visual comparison with analogous areas on the ground control maps. Image evaluation centered on the ability of the analyst to both <u>detect</u> and <u>identify</u> resources. These comparisons between and among images and ground-control maps, formulated the basis for preparation of a feasibility diagram (see Table 4.3) which initially assessed the interpretability of the ERTS-1 images. High altitude false-color infrared imagery was also evaluated.

The results shown in Table 4.3 generally indicate and equate interpreter ability to detect resources; however, object identification generally appears more diffiuclt. The MSS green band no. 4 appears useful in Eastside Valley and Basin Front Sagebrush-Scrub identification, and in the detection of main highways and logging roads. The MSS red band no. 5 has been assessed as useful in identification of Fir forest, Intermediate Interior Valley Xeric grassland, Mesic Cultivated croplands, Mesic rangeland, Xeric Eastside grassland-Scrub rangeland, sedimentary bedrock, standing water and highways and logging roads. Perhaps the least useful single band

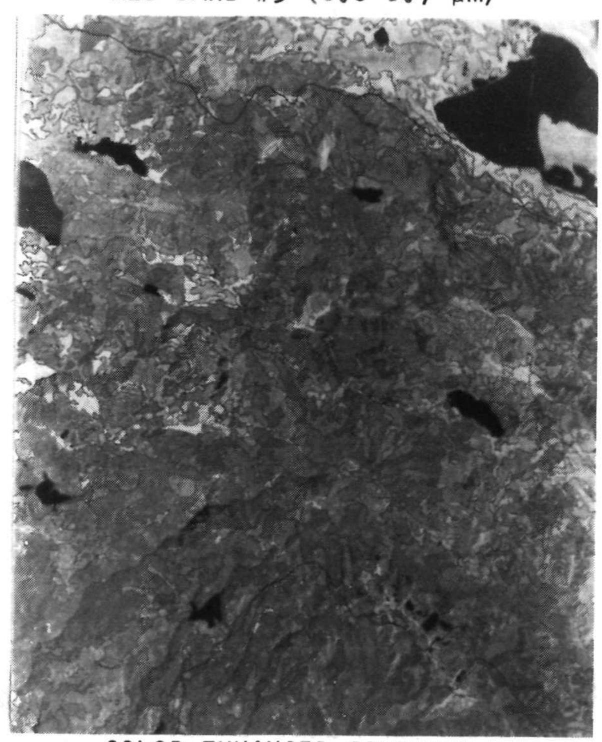


GREEN BAND #4 (0.5-0.6 μm)



RED BAND #5 (0.6-0.7 μm)

INFRARED BAND #7 (0.8-1.1 μm)



COLOR ENHANCED COMBINED
BANDS #4-#5-#7 (0.5-1.1 μm)

Figure 4.8. Vegetation/terrain resources of the Feather River Watershed region (2.5 million acres) as determined on ERTS-1 imagery (7-26-72). Black-and-white MSS bands and the false color composite image (MSS 4,5,7) are presented. These line delineations were related to ground control maps which provided the basis for preparation of the feasibility table shown on the following page.

TABLE 4.3. THE FEASIBILITY OF WILDLAND LANDSCAPE FEATURE DETECTION AND IDENTIFICATION WITHIN THE FEATHER RIVER WATERSHED REGION ON HIGH ALTITUDE AND ERTS-1 IMAGERY

LEGEND

- ••• EASILY DETECTABLE
- •• MARGINALLY DETECTABLE
- • NOT DETECTABLE

- ••• EASILY IDENTIFIABLE
- •• MARGINALLY IDENTIFIABLE
- • NOT IDENTIFIABLE

IMAGERY PARAMETERS										
VEHICLE	HIGH ALT. RB57		ERTS-1		ERTS-1		ERTS-1		ERTS-1	
SENSOR SYSTEM	RC-8 CAMERA		MSS BAND #4		MSS BAND #5		MSS BAND #7		MSS BANDS 457	
MISSION - DATE[a]	MX 139(7-25-70)		(7-25-72)		(7-25-72)		(7-25-72)		(7-25-72)[b]	
ORIGINAL IMAGE TYPE	FALSE COLOR IR		B&W TRANS.		B&W TRANS.		B&W TRANS.		CIR ENHAN. IR.	
INTERPRETED IMAGE TYPE	CIR TRANS.		B&W PRINT		B&W PRINT		B&W PRINT		COLOR PRINT[c]	
ORIGINAL FORMAT	9 X 9 in.		9 X 9 in.		9 X 9 in.		9 X 9 in.		9 X 9 in.	
INTERPRETATION FORMAT	9 X 9 in.		16 X 20 in.		16 X 20 in.		16 X 20 in.		16 X 16 in.	
IMAGE SPECTRAL RANGE	0.4 - 0.9μm		0.5 - 0.6μm		0.6 - 0.7μm		0.8 - 1.1μm		.5-.7 & .8-1.1μm	
ORIGINAL IMAGE SCALE	1:120,000		1:1,000,000		1:1,000,000		1:1,000,000		1:1,000,000	
OBJECT RESOLUTION	20-30 FT.		200-300 FT.		200-300 FT.		200-300 FT.		200-300 FT.	
INTERPRETATION RESULTS	D*	I**	D*	I**	D*	I**	D*	I**	D*	I**
FOREST RESOURCES										
Coniferous Forests	•••	•••	••	••	••	••	••	•	•••	••
A. High Elevation Red Fir Forest	•••	•••	••	•	•••	•••	•	•	•••	••
B. Westside Intermediate Mountain Conifer	•••	•••	••	••	•••	••	••	•	••	••
BB. Eastside Intermediate Mountain Mixed Conifer	••	••	••	•	••	•	•	•	•	•
C. Eastside Intermediate Pine-Scrub Forest	•••	•••	•••	••	•••	••	•	•	••	••
D. Eastside Northern Juniper Woodland	••	••	•	•	•	•	•	•	•	•
E. Eastside Timberland-Chaparral Complex	•••	•••	••	••	•••	••	•	•	•••	••
Hardwood Forests	•••	•••	••	•	••	••	•	•	••	•
F. Intermediate Mountain Xeric Hardwoods	•••	•••	••	•	••	•	•	•	••	••
G. Westside Foothill Pine-Oak Woodland	•••	•••								
GG. Westside Foothill Oak Woodland-Grass	•••	•••								
GC. Westside Foothill Oak Woodland-Chaparral	•••	•••								
GGC. Westside Foothill Oak Woodland-Grass-Chaparral	•••	•••								
H. Mixed Mesic Hardwood Communities	•••	•••	•	•	•	•	•	•	•	•
I. Westside Foothill Mixed Hardwood-Conifer Forest	•••	•••								
NON-FOREST RESOURCES										
Chaparral	•••	•••	••	••	••	••	••	•	•••	••
J. Westside Valley Front Foothill Chaparral	•••	•••								
K. Westside Intermediate Mountain Chaparral	•••	•••	••	•	•••	••	••	•	•••	••
KK. Eastside Intermediate Mountain Chaparral	•••	•••	••	••	•••	••	••	•	•••	••
L. Eastside Valley and Basin Front Sagebrush Scrub	•••	•••	•••	•••	•••	••	•	•	•••	••
Grassland-Meadow-Marshland Complex	•••	•••	••	•	••	•	•	•	•••	••
M. Subalpine Grassland										
N. Intermediate Interior Valley Xeric Grassland	•••	•••	•••	••	•••	•••	•	•	•••	•••
O. Mesic Meadow Complex	•••	•••	••	•	••	••	•	•	•	•
P. Freshwater Marshland	•••	•••	•••	••	•••	••	••	•	•••	•••
AGRICULTURAL AND RANGELAND RESOURCES										
Q. Mesic Cultivated Croplands	•••	•••	••	•	•••	•••	•••	•••	•••	•••
R. Mesic Rangeland	•••	•••	••	••	••	•••	•	•	••	•••
S. Xeric Eastside Grassland-Scrub Rangeland	•••	••	•••	••	•••	•••	•	•	•••	•••
OTHER LANDSCAPE FEATURES										
T. Forest Plantation Sites	•••	•••	•••	••	•••	••	•	•	•••	••
U. Urban-Residential-Commercial Sites	•••	•••	••	•	•••	•	•	•	••	•
V. Exposed Soil	•••	•••	••	••	••	••	•	•	••	••
W. Exposed Bedrock	•••	••	•••	••	••	••	•	•	••	••
WB. Basalt	•••	•••	••	•	••	•	•	•	•••	•••
WA. Andesite	•••	••	••	•	•••	••	•	•	••	•
WR. Rhyolite	••	••								
WP. Pyroclastics	•••	••	••	•	••	•	•	•	••	••
WG. Granite	•••	•••	••	•	•••	••	•	•	••	••
WU. Ultrabasics	•••	•••	••	•	•••	•	•	•	•••	••
WS. Sedimentary	•••	•••	••	•	•••	•••	••	•	••	•••
WM. Metavolcanics	••	••	•	•	•	•	•	•	•	•
HYDROLOGIC RESOURCES										
X. Standing Water	•••	•••	••	••	•••	•••	•••	•••	•••	•••
Y. Running Water	•••	•••	•	•	••	••	•	•	••	••
Z. Snowpack	•••	•••								
MISCELLANEOUS FEATURES										
ZA. Recent Fire Scar	•••	•••	•	•	••	•	•••	••	•••	••
ZB. Main Highway	•••	•••	•••	•••	•••	•••	•	•	•••	••
ZC. Landslide Scar	•••	•••	••	•	•••	•	•	•	••	••
ZD. Logging Roads	•••	•••	••	•••	•••	•••	•	•	••	••

* DETECTION .... THE ABILITY TO DISCRIMINATE AN IMAGE ENTITY FROM THE SURROUNDING TONE MATRIX.

** IDENTIFICATION .... THE ABILITY TO CLASSIFY AND ASSIGN A NAME TO AN IMAGE DETERMINED BY ITS UNIQUE CHARACTERISTICS SUCH AS COLOR, TONE, TEXTURE, SHAPE, PATTERN, SIZE, ASSOCIATION OR OTHER QUALITY.

[a] Feasibility of image identification includes consideration of sequential imagery.
[b] MSS color-combined enhanced image transparency.
[c] The enlarged print used in this interpretation was fifth generation.

image with respect to object identification is the infrared band no. 7, where only Mesic Cultivated croplands, and standing water are clearly identifiable. Furthermore, these results indicate interpreter ability to identify the following wildland resources on the MSS 4-5-7 false-color combined image: Intermediate Interior Valley Xeric grassland, Fresh water marshland, Mesic Cultivated croplands, Mesic rangeland, Xeric Eastside grassland-Scrub rangeland, Exposed Basalt bedrock, sedimentary rock, and standing water.

Table 4.4 shows projected interpretation time and costs associated with the task of producing vegetation/terrain resource maps from both high altitude and ERTS-1 imagery. Approximately sixty high altitude images, compared with one ERTS-1 image, are needed to compile a complete regional map. The total time required for imagery interpretation, including resource type classification, has been estimated to be seven times greater on high altitude than on ERTS-1 imagery. This coincides with a projected cost ratio on a per/acre basis, of 7:1, respectively. Of importance to these projected time and cost data, however, is the significant difference in resource information content between the aircraft and satellite images. The amount of resource information lost on the ERTS-1 image, however, remains to be assessed.

4.2.1.4 <u>ERTS-1 Intensive Site Imagery Analysis</u>

<u>Methods and Procedures</u>

The approach used toward developing manual techniques for ERTS-1 imagery analysis has been initially confined to the Davis Lake intensive study area, although methods and procedures are applicable throughout the entire region. The method of enlarging the intensive study area, which is about

TABLE 4.4. PROJECTED INTERPRETATION TIME AND COSTS OF REGIONAL FEATHER RIVER WATERSHED IMAGE ANALYSIS

TASK	HIGH ALTITUDE CIR TRANSPARENCY (9 x 9 in.)	ERTS-1 COLOR ENHANCED FALSE-COLOR ENLARGED PRINT (16 x 16 in.)
DELINEATION OF WATERSHED BOUNDARY (2.5 MILLION ACRES)	3.0 HOURS	0.5 HOURS
PLOTTING EFFECTIVE AREAS	5.0 HOURS	0.0 HOURS
DELINEATION OF HOMOGENEOUS AREAS	48.0 HOURS	3.0 HOURS
PHOTO INTERPRETATION TRAINING & TESTING	6.0 HOURS	2.0 HOURS
RESOURCE TYPE CLASSIFICATION	210.0 HOURS	30.5 HOURS
TOTAL INTERPRETATION TIME REQUIRED	272.0 HOURS	35.5 HOURS
HOURLY WAGE	$7.00/HOUR	$7.00/HOUR
TOTAL INTERPRETATION COSTS (TIME)	$1,904.00	$248.50
TOTAL COST/ACRE	0.07¢	0.0098¢
COST RATIO	7	1

4 percent of the 9 x 9 ERTS-1 color composite image, involved the use of a Simmon Omega variable condenser with a Componon 1:5.6/135 Schneider Kreuznach lens. The single ERTS-1 image, July 26, 1972, was projected downward onto high quality white bond paper to a scale of 1:250,000.

One eighth inch diameter test cells (0.196 square miles on the ground) were established on a random basis within the homogeneous delineated areas (scale 1:250,000). The total sample population area (59 mi^2) represents about 9 percent of the Davis Lake intensive study area (630 mi^2). Distribution of the 300 test cells is seen in Figure 4.9. This figure contains "overlays" of mean annual percipitation and elevation zonation, exemplary of interpretation aids.

The 1970 Munsell Book of Color was used to quantify the color attributes (hue, value, chroma) of each of the test cell circles, independent of resource delineation or classification. Interpolation of Munsell Color data was necessary in many instances since subtle color variation between the projected color within the test cell area and the Munsell Color chips often existed.

The resource classification of each test cell, with the associated Munsell color determination, provides the basis for the derivation of ERTS-1 image interpretation keys specific to the area and the image used. The technique used in establishing these keys to wildland resources is applicable, however, to any ERTS-1 image.

<u>Development of Interpretation Keys</u>

Another expression of the Munsell color data which quantifies the Davis Lake resources color attributes on the ERTS-1 image is presented in Figure 4.10.

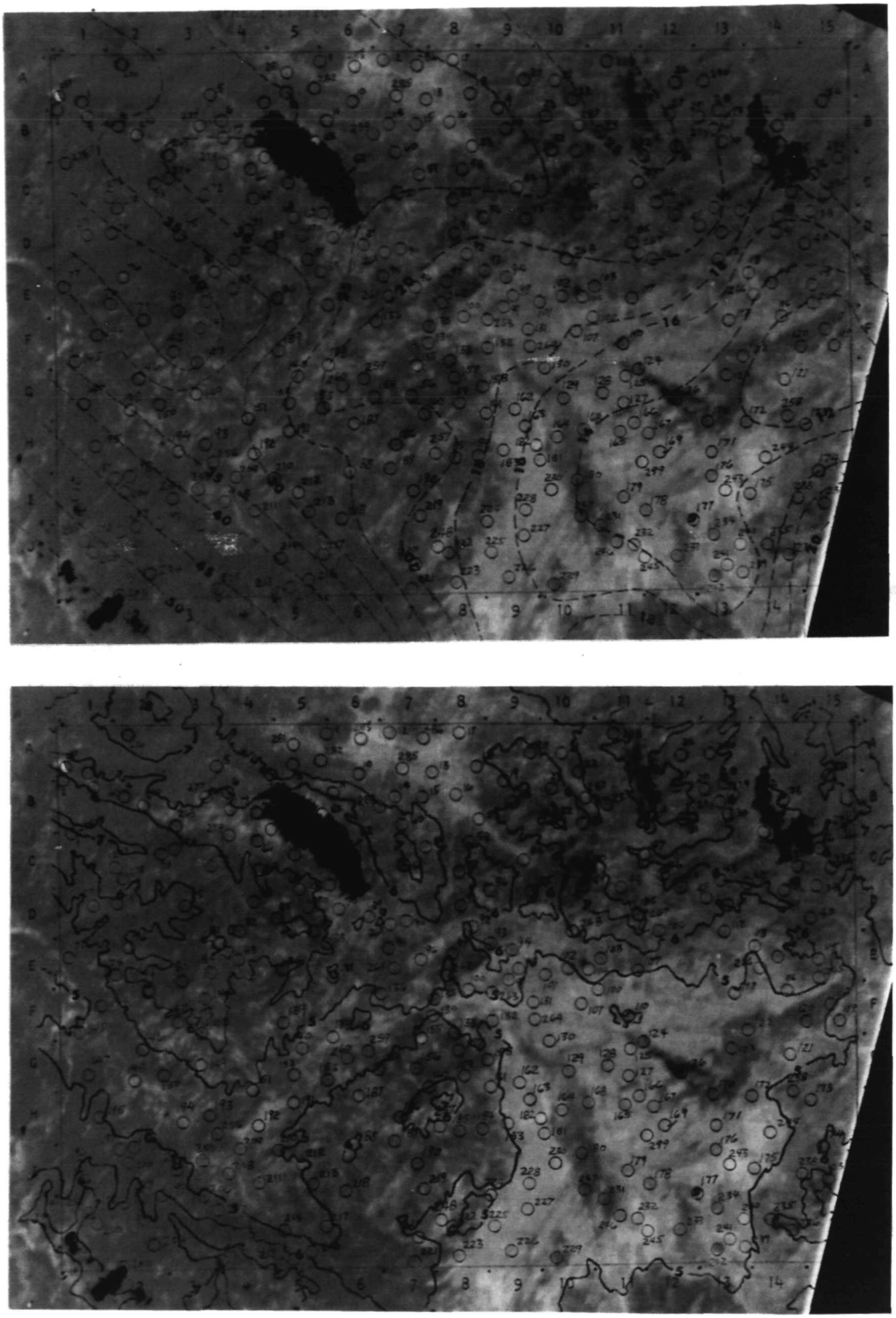


Figure 4.9. Mean annual precipitation overlay (top) and elevation zonation with 1000 foot contour interval overlay (bottom) on projected ERTS-1 image of the Davis Lake intensive study area. The numbered circles are 0.196 mi^2 test cells used in the quantitative interpretation test. Davis Lake (upper center) is five miles long (original image scale = 1/250,000).

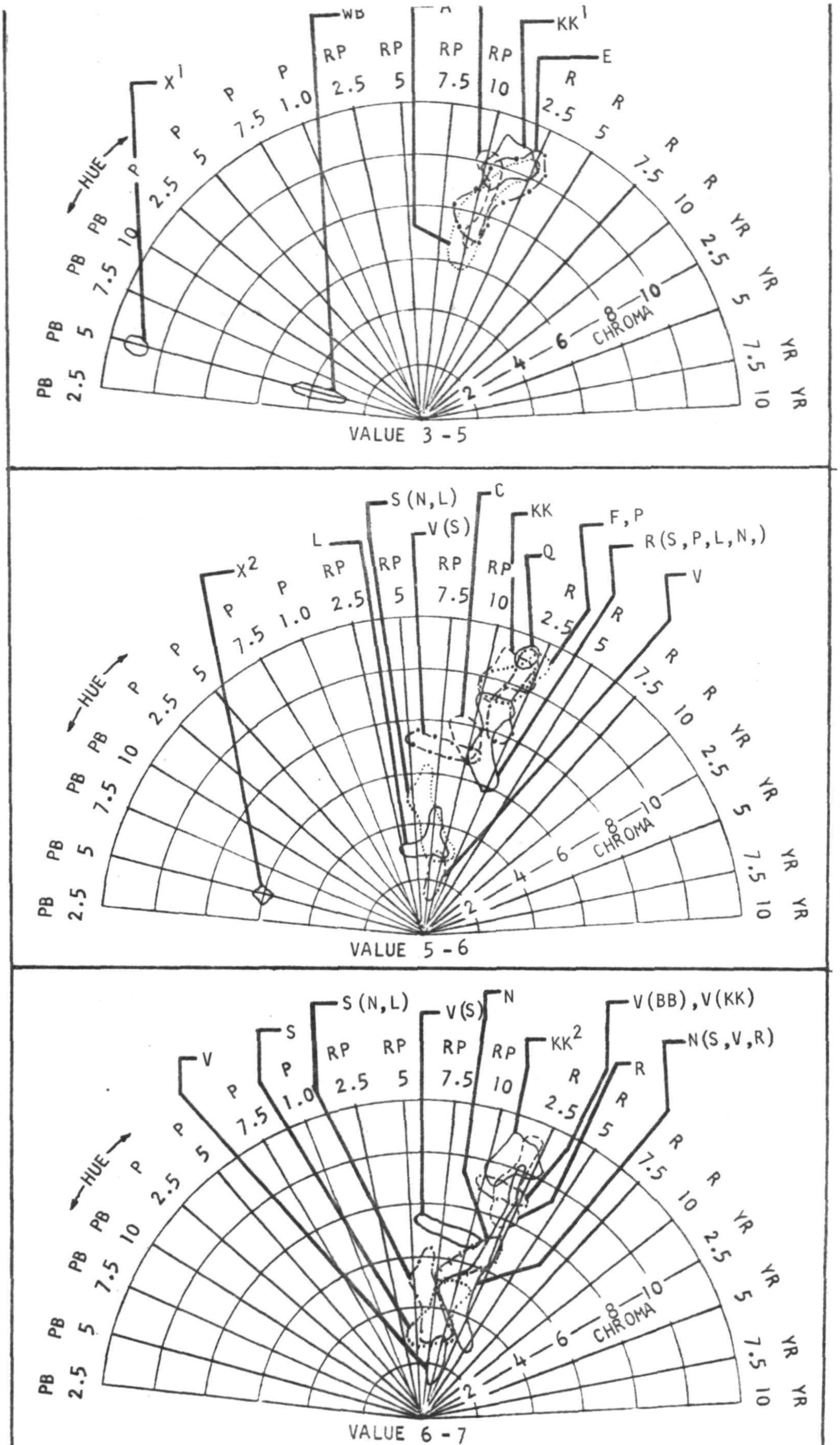


Figure 4.10. These Munsell color diagrams illustrate the relative degree of discrimination between and among wildland resource entities within the Davis Lake study area. (See text for explanation.)

These diagrams are two dimensional renditions of a hue section (2.5PB-10YR) of the color solid. In Figure 4.10 color value (brightness) increases toward the bottom, thus the sequence adds 3-D to the illustration. It is apparent that several types (X,WB,V/S,V) are readily separate from the others, and thus are detectable and probably identifiable. Difficulty in separating many resources is also apparent, since a significant degree of color tone overlap occurs between and among them. Within the 3-5 value range, saturated reddish purple to red colored resources (BB,KK,E,A) overlap considerably. The chaparral (KK), however, could probably be distinguished from Fir forest (A) on the basis of subtle hue and saturation differences. It is apparent that resource types L, S(N,L),V,V(S)S separate easily from the other present, since the hue ranges are very low in saturation and are greyish-reddish-purple in color tone. The resource types KK, C,Q,F,P,R(S,P,L,N) generally overlap over the chroma range 6-11 in the red-purple to red hue range. However, even several of these types can be differentiated based on chroma separation and subtle hue variations. In the very light tone signature resources, value 6-7, many types are distinguished based on chroma separations and subtle hue variations. Consequently, these Munsell color diagrams in themselves represent useful interpretation guides to resource discriminations on ERTS-1 imagery, although they may be applicable only to this particular color composite image. For any other color composite image which may have been processed slightly differently than the one used in this test, the general degree of color discrimination between resource entities would be similar to what is shown in Figure 4.10, but the absolute color notations would be slightly different.

Munsell color ranges, corresponding ISCC-NBS color names, and precipitation and elevational data, provided the basis for constructing a dichotomous interpretation key specific to 18 resource categories. This key proved to be too complex for use in practical photo interpretation and required simplification for actual use.

The interpretation key (see Figure 4.11), used in the quantitative ERTS-1 interpretation experiment, is a simplified version of the original key which contained Munsell color range notations. The modified key replaces these data with word descriptors of color ranges. Training cells were provided to guide the interpreters through the key.

An ERTS-1 Quantitative Image Interpretation Test

The purpose of this interpretation test experiment was to quantitatively assess the ability of two interpreters to utilize the ERTS-1 image interpretation key (see Figure 4.11) to identify and classify wildland resources within the Davis Lake intensive study area. The NASA Goddard ERTS-1 false-color composite (MSS 4-5-7) image was used in the test. It should be emphasized, however, that the vegetation/terrain entities are of an ecologically diverse nature and often confound interpretation by occurring in varying proportions within homogeneously appearing areas.

The test was given to two skilled interpreters. Interpreter A was familiar with the Davis Lake study area resources, but Interpreter B generally was not. The ERTS-1 image was projected on to the 300 test cells indicated in Figure 4.9. Acetate overlays of precipitation and elevational zonation aided the decision making process. Sixty-seven specific known resource training cells were indicated on the answer sheet provided, such

2. Color dark blue; resource boundary distinct (see test cell No. 35) .... STANDING WATER (LAKE OR RESERVOIR) (X)

2. Color moderately dark blue; resource boundary not necessarily distinct.

3. Color is more saturated with blue, light blue, boundary distinct .... STANDING WATER, SHALLOW POND WITH HIGH SEDIMENT OR SALT CONTENT (X)

3. Color is less saturated; boundary indistinct; resource often mottled with light tones and red colorations .(No. 52) .... EXPOSED BASALT BEDROCK (WB)

1. Color is red, ranging from very pale or light gray-red, light pruplish gray-red or other pale color variants, to moderate strong, bright, saturated or dark red, orange-red or purplish red.

4. Colors are mostly moderately dark to strongly saturated or dark red (Nos. 4,55,84,82,144,294,252); some tones appear bright (Nos. 143,199, 273)

5. Red color tones are moderately dark (Nos. 79,93,160), but color may be strong or saturated and red to red-orange (No. 188). The resource is often mottled with pale lighter tones (Nos. 93, 267) .... EASTSIDE INTERMEDIATE MOUNTAIN CHAPARRAL (KK)

5. Red color tones are mostly dark and colors range from a dark purplish-red (Nos. 49, 85) to dark strong red (Nos. 156, 206, 25, 28) and dark orange-red (Nos. 144, 31, 214)

6. Mean Annual Precipitation (MAP) predominantly ranges 30-50 inches; Color tone is dark purplish red to dark purplish brownish red (Nos. 4, 274). Resource occurs in smaller scattered areas.

7. Elevational range: 7000 - 8000 feet (+) .... FIR FOREST (RED FIR) (A)

7. Elevational range: 5000 - 7000 feet (±) .... FIR FOREST (WHITE FIR) (A)

6. MAP ranges from less than 40 inches.

8. MAP ranges 18 - 30 inches; color is moderate red, moderate purplish red (Nos. 95, 221), to light purplish red (Nos. 29, 115); Elevational range 5000 - 6000 feet .... EASTSIDE INTERMEDIATE PINE-SCRUB FOREST (C)

8. MAP ranges 18 - 35 inches; color is moderately dark, saturated, or strong.

9. Color is mostly strong orange-red, strongly red (No. 144) or purplish red (No. 217). Elevational range is 5000 - 7000 feet; Resource type is extensive .... EASTSIDE TIMBERLAND CHAPARRAL COMPLEX

9. Color is less orange-red, more strongly red to moderate purplish-red (Nos. 9, 80, 256); elevational range is 4000 - 7000 feet; this resource type is transitional .... EASTSIDE INTERMEDIATE MOUNTAIN MIXED CONIFER (BB)

4. Colors are moderately light (Nos. 171, 228) and bright (No. 122) to very bright (No. 118) and light (No. 243) in tone, <u>except</u> for dark pinkish gray areas. (Nos. 10, 131, 174).

10. Colors range from purplish red-gray (No. 174) to gray-pink (No. 192); Colors are low in saturation

11. Color tone relatively dark purplish red-gray (No. 174) to moderately dark pinkish gray (No. 171) (high to low density, respectively); saturation is low; elevational range 4000 - 6000 feet .... EASTSIDE VALLEY AND BASIN FRONT SAGEBRUSH-SCRUB (L) (L-6,Dense) (L-4,Sparse)

11. Color tone lighter; light or pale purplish gray (No. 127); Elevational range 4000 - 5000 feet .... XERIC EASTSIDE GRASSLAND SCRUB RANGELAND (S)

10. Colors range from light pink to pale orange-red.

12. Color tone is varied; color saturation may be strong, but generally is not.

13. Color tone is moderately light (No. 47) to very light (No.63); Resource associated wtih bright red to moderate orange-red mesic rangeland areas. This type is not extensively homogeneous within this region .... INTERMEDIATE INTERIOR VALLEY XERIC GRASSLAND (N)

13. Color tone is less than moderately light. (No. 47)

14. Color saturation is moderate (Nos. 38,218, 5, 94); Color tone is moderate but may be <u>very</u> light(No.182) where soil is completely void of vegetation cover .... EXPOSED SOIL OR ROCK WITH SPARSE GRASS OR CHAPARRAL COVER (V), (W), (V-KK)

14. Color saturation is moderately low; tones are moderate; color may be grayish (No.130) or pinkish gray(Nos.128, 192)..... MIXED GRASSLAND SCRUB RANGELAND. S(R,L,N)

12. Color tone is moderate to light; color saturation is usually strong to bright; color appears strong pink, red or red orange.

15. MAP ranges 10 - 40 inches.

16. Elevation ranges 4000 - 7000 feet; Map ranges 20 - 30 inches; resource mix varied, occurs as pale gray-red N(S) (No.33) or slightly brighter red N(R) (No. 65); resource type varied and not extensive .... MIXED XERIC GRASSLAND N(R), N(L), N(S)

16. Elevation ranges 4000 - 7000 feet

17. Elevation ranges 4000 - 5000 feet; pattern discernible as small squares or areas with right angle corners (No.176). MAP ranges 10 - 14 inches; color is bright to moderate red or red- orange (No.122) .... CULTIVATED CROPLANDS (Q)

17. Elevation varied; right angular pattern not discernible.

18. MAP ranges 10 - 14 inches; elevation ranges 4000 - 6000 feet; color is red-orange often occurring as strong bright red of pink areas within extensive dark red or purplish-red areas (No. 194); resource may appear elongate .... MESIC RANGELAND (R)

18. MAP ranges 14 - 35 inches.

19. Elevation ranges 5000 - 7000 feet; MAP 18 - 35 inches; very few extensive homogeneous areas of this resource occur within this region .... INTERMEDIATE MOUNTAIN XERIC HARDWOOS (F)

19. Elevation ranges 400 - 5000 feet; MAP ranges 12 - 16 inches; color mottled red to dark purplish red (No. 124, 170); resource often elongate occurring within gray areas; associated with bright strong red areas (No. 229)... MARSHLAND (P)

Figure 4.11. An ERTS-1 image interpretation key to wildland resources within the Davis Lake study area of the Feather River Watershed region.

that the interpreter could study the variations in tone signatures. Each interpreter was asked to identify approximately 200 test cell areas with respect to (1) specific dominant vegetation/terrain resource type, and (2) general resource type. The identity of each training and test cell has been verified by analysis of high altitude CIR imagery and ground observation data (see Figure 4.6).

Results of the interpretation test given to Interpreters A and B are presented in Tables 4.5 and 4.6. The "no. indicated" refers to the number of test cells which the interpreter indicated were of a certain resource type. The "no. omitted" refers to the number of cells of a certain resource type that the interpreter omitted. Commission error contrasts with omission error in that it refers to the accumulation of incorrect interpretations (e.g., when type "A" is incorrectly called type "B", two errors have been made -- "A" has been omitted and "B" committed). The number of test cells known to be of a certain resource type from ground control information is also indicated in these tables.

The results of this photo interpretation test are expressed as percent correct, percent omission, and percent commission error. Commission error is expressed as the number of errors of a type based on (1) the total number of the resource type present in the test or (2) the number of errors of a type based on the total number of that type indicated.

The results of specific resource type identification on the ERTS-1 image are presented in Table 4.5. Overall they indicate that both interpreters were about 65 percent proficient in interpreting all resources on the image. Both interpreters correctly identified all standing water

TABLE 4.5. RESULTS OF THE INTERPRETATION TEST USING ERTS-1 IMAGERY OF SPECIFIC VEGETATION/TERRAIN TYPES

SPECIFIC RESOURCE TYPE	NO. TEST CELLS	INTERPRETER IDENTIFICATION	NO. INDICATED	NO. OMITTED	NO. CORRECT	NO. COMMISSION ERROR	PERCENT OMISSION	PERCENT COMMISSION (I)[c]	PERCENT COMMISSION (II)[d]	PERCENT CORRECT
A	10	A[a]	7	3	7	0	30	0	0	70
		B[b]	9	4	6	3	40	30	33	60
BB	10	A	4	8	2	2	80	20	50	50
		B	2	9	1	1	90	10	50	10
. C	9	A	13	4	5	8	44	88	61	55
		B	11	4	5	6	44	66	54	55
E	35	A	38	5	30	8	14	22	21	85
		B	53	5	30	23	14	65	43	85
F	3	A	1	3	0	1	100	33	100	0
		B	0	3	0	0	100	0	0	0
KK	29	A	32	6	23	9	20	31	28	79
		B	24	10	19	5	34	17	20	65
L	24	A	30	2	22	8	8	33	26	91
		B	19	12	12	7	50	29	36	50
N	9	A	0	9	0	0	100	0	0	0
		B	7	5	4	3	55	33	42	44
P	3	A	1	2	1	0	66	0	0	33
		B	1	2	1	0	66	0	0	33
Q	5	A	3	2	3	0	40	0	0	60
		B	3	2	3	0	40	0	0	60
R	21	A	23	3	18	5	14	23	21	85
		B	19	5	16	3	23	14	15	76
S	16	A	14	6	10	4	37	25	28	62
		B	23	0	16	7	0	43	30	100
V	6	A	5	5	1	4	83	66	80	16
		B	5	4	2	3	66	50	60	33
W	8	A	2	7	1	1	87	12	50	12
		B	0	8	0	0	0	0	0	0
WB	4	A	4	0	4	0	0	0	0	100
		B	3	2	2	1	50	25	23	50
X	6	A	6	0	6	0	0	0	0	100
		B	6	0	6	0	0	0	0	100
TOTAL	198	A	183	55	133	50	32	25	27	67
		B	185	75	123	62	37	31	33	62

[a] Results for Interpreter A

[b] Results for Interpreter B

[c] Error based on number of type present

[d] Error based on number of a type indicated

TABLE 4.6. RESULTS OF THE INTERPRETATION TEST USING ERTS-1 IMAGERY OF BROAD VEGETATION/TERRAIN TYPES

COMPONENTS	A, BB, C, E		F, H		KK, K		N, N(V)		Q		R, P		L, S		V, W, WB		X			
COMPREHENSIVE RESOURCE	CONIFEROUS FOREST		HARDWOOD FOREST		MOUNTAIN CHAPARRAL		XERIC GRASSLAND		CULTIVATED CROPS		MESIC RANGELAND		SAGEBRUSH SCRUB		EXPOSED SOIL		STANDING WATER		TOTALS	
NO. TEST CELLS	71		4		31		17		4		23		44		10		6		210	
INTERPRETER ID	A[a]	B[b]	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
NO. CORRECT	57	60	0	0	23	19	0	4	4	3	22	17	36	32	7	4	6	6	155	145
NO. COMMISSION	6	15	1	0	9	5	0	3	0	0	4	4	7	8	5	3	0	0	32	38
NO. INDICATED	63	75	1	0	32	24	0	7	4	3	26	21	43	40	12	7	6	6	187	183
NO. OMITTED	14	11	4	4	8	12	17	13	0	1	1	6	8	12	3	6	0	0	55	65
PERCENT OMITTED	19	15	100	100	25	38	100	76	0	25	4	26	18	27	30	60	0	0	26	30
PERCENT COMMITTED[c]	8	21	25	0	29	16	0	17	0	0	17	23	15	18	50	30	0	0	15	18
PERCENT COMMITTED[d]	9	20	100	0	28	20	0	42	0	0	15	19	16	20	41	42	0	0	17	20
PERCENT CORRECT	80	84	0	0	74	61	0	23	100	75	95	73	81	72	70	40	100	100	73	69

[a] Results for Interpreter A

[b] Results for Interpreter B

[c] Error based on number of type present

[d] Error based on number of a type indicated

bodies (X), and showed generally high proficiency (>60 percent) in correctly identifying Fir forest (A), Eastside timberland-chaparral forest (E), Mountain chaparral (KK), Eastside Valley and Basin Front Sagebrush-Scrub (L), Cultivated croplands (Q), Mesic rangeland (R), Xeric Eastside grassland-Scrub rangeland (S), and Exposed Basalt. Among these resource types, commission errors were generally low (>35 percent) except for high commission error for the timberland-chaparral type (E) by Interpreter B.

Omission errors were also generally low (see Table 4.5) indicating interpreter ability to detect these resources where they occur as varying tone signatures. A high (50 percent) omission error occurred for Exposed Basalt by Interpreter B since he was biased toward identifying surrounding timber types (correctly) as opposed to the test cell type (WB). This result no doubt reduces the overall percent correct otherwise obtainable.

Marginal interpreter proficiency was demonstrated for resource types BB, C, N, P, V, and W, while neither interpreter correctly detected nor identified the few hardwood types presented. Combined interpreter results compared well with the feasibility indicators (presented in Table 4.3) except for resource types L, KK, E, and A which were more easily identifiable than expected.

It is apparent that Interpreter A detected no Xeric grassland (N) types and Interpreter B detected no exposed rock (W) types although both types were present. In most cases, difficulty was encountered in distinguishing among V, W, N resource types; A, BB, E resource types; and C, KK, R resource types. These results were apparent in the test correction process. From these results (Table 4.5), it is apparent that the most difficult

types to detect were BB, F, P, V, C, and W, and proficiency in correctly identifying these resources was low.

Results presented in Table 4.6 indicate high interpreter proficiency in interpreting broad resource types including coniferous forests, cultivated croplands, standing water bodies, sagebrush types, mesic rangeland-marshland, and mountain chaparral. Exposed soil and bedrock proved marginally identifiable by Interpreter B but more easily identifiable by Interpreter A. Both xeric grassland areas and hardwood forests were virtually undetectable resource entities and, therefore, were not identified correctly. Among the broad resource types present in the Davis Lake study area, both interpreters were about 70 percent correct overall in their interpretations. However, with increased training these results probably could have been improved.

Conclusions

The quantitative interpretation test results presented in the previous section indicate the relatively high interpretability of major resources within the Davis Lake study area of the Feather River Watershed region. High proficiency in resource identification was demonstrated by both interpreters for nine specific resource types. As expected, due to heterogeneity among types, certain types were difficult to separate and identify and often were confounded in the process of interpretation. However, those resource types deemed uninterpretable in the above test might yet prove interpretable if (1) the key were more explicit, (2) multidate imagery were used, (3) enhancements were devised to increase the proficiency of interpretation, and (4) interpreter training and experience increased.

In this study, a procedure and technique for the development of ERTS-1 interpretation guides and keys has been demonstrated. The Munsell Color System, used to quantify color data and transformed into guides and keys, can prove useful in interpreting ERTS-1 images. Likewise, both precipitation and elevational data proved useful in aiding resource identifications in the Davis Lake study area.

It is apparent from these initial evaluations that ERTS-1 imagery interpretation is relatively rapid and less costly, in terms of time, than similar analysis performed on high altitude aircraft imagery. The level of information loss between these "stages" of imagery remains to be assessed. Without doubt, the high altitude CIR imagery provides a means for accurate regional resource analysis and mapping, a capability previously unrealized. Synoptic ERTS-1 imagery provides the means for continuous regional resources evaluation while high altitude imagery provides for immediate detailed area analysis.

4.2.1.5 Snow Surveys

Project Objectives

The research objectives for the snow mapping project during this reporting period were twofold. First, sequential U-2 high flight photography and field data were used to develop a suitable reference document, in the form of an image interpretation key, which could effectively be used by a trained image analyst when interpreting areal extent of snow in forested areas. Second, an efficient manual analysis technique was developed for estimating acreages of snow. This technique capitalizes on the human's ability to amalgamate information on (1) the appearance of snow as seen on high flight

photos and (2) the type, density and distribution of the vegetation/terrain within which the snow occurs and which greatly influences the appearance of snow.

Methods and Procedures

In the past, the major difficulty in studying snow cover over vast areas within the Feather River Watershed was the lack of suitable synoptic view imagery. During the 1970-71 melt season, small scale (1:100,000) 70 mm black-and-white photographs were procured (by a private contractor) on five different occasions. Only the Spanish Creek Watershed was flown, and more than 80 photographs were required to cover this area. During the 1971-72 season, the NASA U-2 aircraft stationed at the Ames Research Center flew four missions, each of which covered the entire Feather River Watershed. In addition, a U-2 aircraft flew a solo flight line centering over the Spanish Creek Watershed on May 21, 1969. Consequently, during this last reporting period, a sufficient amount of imagery was available for study.

In support of the recent U-2 missions, two methods were employed for collecting field data on true snow conditions -- field sampling and low altitude oblique aerial photography. On three dates in 1972, January 31, March 6 and March 28, a field crew visited a series of permanent plots established within the Spanish Creek watershed. (These plots were described and illustrated in last year's annual progress report.) The field crews traveled by snowmobile and on snowshoes to each plot location. Snow depth and condition data were collected and recorded, consistent with California Cooperative Snow Survey procedures using Mount Rose snow sampling tubes.

Data collection on the ground, however, was very tedious and time

consuming. Furthermore, only a few samples could be collected before so much time had elapsed that further sampling became meaningless with respect to a specific high flight mission. Consequently, the primary mode of ground data collection was with low altitude aerial oblique photography. By maintaining a flying altitude between 500 and 1000 feet above ground and employing a 35 mm camera, with wide angle lens, color oblique photographs were taken which provided enough detail to ascertain the presence or absence of snow and which were snyoptic enough to provide good snow boundary information. Each permanent ground plot site, as well as many other targets of opportunity, were photographed in 1972 on January 10, January 31, March 28 and May 3.

Development of an Image Interpretation Key

A comprehensive image interpretation training and reference document was prepared which was designed to aid the trained image analyst while evaluating snowpack conditions as seen on synoptic view imagery. The primary value of this key is that it documents, in the form of word descriptions and photo illustrations, the appearance of snow when influenced by a variety of vegetation/terrain conditions. Thus, a selective type of key was prepared based on eight vegetation/terrain categories -- dense conifer forest, sparse conifer forest, dry site hardwood forest, brushland, meadow or rangeland, urban land, water or ice, and rock or bare ground. Within each category, examples were chosen under different conditions of elevation, steepness of slope and direction of slope (aspect). For example, within dense conifer forests snowpack conditions are described for (1) high elevation and steep north slopes, (2) high elevation and moderate

north slopes, (3) high elevation and gentle south slopes, (4) medium elevation and flat areas, and (5) low elevation and steep north slopes. Each one of these specific examples represents an entire page in the key and consists of five illustrations -- one before the snow season, two at the height of snow accumulation and two during the depletion period (see Figure 4.12). In the completed version of the key the eight vegetation/terrain type categories are illustrated with a total of twenty-two specific examples, each similar to the one shown in Figure 4.12.

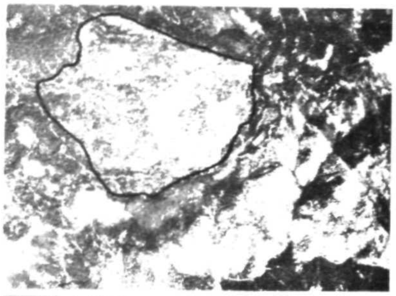
Possibly the most important value of the image interpretation key is that it allows the image analyst to become cognizant of the fact that for any given area, snow may be present on the ground but may not be visible on the U-2 imagery. This situation often occurs within a dense coniferous forest in which a deep snowpack can be completely observed by the crown canopy. It has been emphasized in the key, however, that the presence of snow in a dense forest usually can be deduced merely by examining the appearance of adjacent vegetation/terrain types. For example, if a dense stand of timber is surrounded by meadows or brushlands and snow can be detected within these adjacent types, the interpreter can safely predict that the dense, heavily shaded timbered area also contains snow.

Development of an Image Interpretation Technique

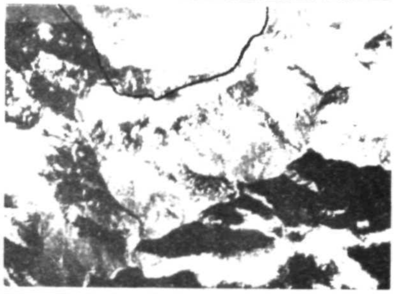
Previous research results (see last year's annual progress report) clearly have shown that four environmental factors greatly influence the appearance of a snow boundary, viz., elevation, slope, aspect and vegetation/terrain type. For example, in certain areas a snow boundary appeared to follow a line of equal elevation but dropped down in elevation considerably

SNOW CONDITIONS WITHIN SPARSE CONIFER FOREST

Density - 0-35% crown closure
Elevation - 5,500 feet
Terrain - gently sloping (0-10^{o}) towards the south



September 21. No snowpack present. Photograph appears medium grey with a pebbly appearance. Roads easily distinguishable due to the lack of canopy interference and appear as white lines.



December 20. Three to four feet of snowpack present. Ground is continuously covered leaving tree crowns and their respective shadows as the only dark areas. The result is a predominant white with a speckling of dark areas. On this photograph, in the upper left hand corner of the indicated area, a dark grey area can be seen with scattered white spots. This is a slightly north facing slope and, due to the sun angle, the shadows have lengthened and now predominate the image appearance. However, snow conditions are the same as in the rest of the sparse conifer forest.

January 31. Over 6 feet of continuous snow cover is present. Sun angle has increased and shadowing has lessened. High reflectivity of the snowpack dominates the scene and the image is predominantly white with a scattering of dark spots.

March 6. Conditions essentially the same as on January 31, except sun angle is even higher, and due to photographic exposure problems, the small dark spots attributable to the trees and shadows are almost lost.

March 28. Snowpack has begun to deplete and is less than 6 feet deep. Due to the low percentage of canopy interference, the position of the snowpack is fairly evident. The areas of lower elevations are reverting to the medium-to-dark grey tone with the very pebbly texture, indicative of the absence of snowpack.

Figure 4.12. Illustrated here is an example page from the image interpretation key which shows snow conditions for a sparse coniferous forest type at high elevation on a gentle south facing slope. The completed version of the key illustrates 22 specific examples, each similar to the one shown here, found throughout the Spanish Creek watershed. The scale of the original U-2 photography used to make the key was 1/440,000 with a ground resolution of approximately 30 feet.

on north facing slopes. In addition, it was found that the presence or absence of snow and consequently the snow boundary was (1) easily detectable in meadows and bare areas, (2) sometimes, but not always, detectable in sparse coniferous forest and (3) nearly impossible to detect in dense coniferous forest. Once an image analyst is properly <u>trained</u> (with an interpretation key) to recognize various combinations of environmental conditions, and is aware of the relationships among these various conditions and the appearance of snow associated with them, he can effectively map snow boundaries on small scale imagery. However, acreage estimates of snow cover, not maps, are needed for making stream flow predictions. Consequently, a new approach to interpretation, using systematic sampling, is being tested which (1) allows a trained analyst to accurately estimate areal extent of snow, (2) can be applied to vast complex forested regions and (3) is fast and inexpensive to implement.

This new technique capitalizes on the ability of the human interpreter to amalgamate several kinds of information and to quickly arrive at a decision. In addition, a new piece of interpretation equipment is employed -- the Bausch and Lomb Zoom Transfer Scope. The interpretation procedure is as follows:

1. Using the Zoom Transfer Scope, observe two forms of data simultaneously -- e.g., a high flight photo and a topographic map annotated with vegetation/terrain information.

2. Place the images of these two forms of data as seen in the Transfer Scope in good register.

3. Adjust the lighting for each image such that each will fade in and

out by adjusting the equipment controls.

4. Place a grid overlay on the topographic map. Note that a certain number of grid intersections fall within each watershed being analyzed and, by adjustment of the lighting on the Transfer Scope, the annotated map with grid can be made to fade in and out of view.

5. For each circular plot (e.g., five acres) within which a grid intersection falls, the interpreter must decide if snow is present. For most plots, the decision is easy, snow obviously is or is not present. However, along the edge of the snowpack boundary the decision is difficult, and the interpreter must concentrate on two things -- appearance of snow and vegetation/terrain condition -- by adjusting the lighting in the Transfer Scope.

6. Classify each circular plot using the following scheme:

Code	Condition
1	No snow present
2	0-20% of ground covered by snow
3	20-50% of ground covered by snow
4	50-100% of ground covered by snow
5	100% of ground covered by snow

7. Examine each circular plot in the watershed and record interpretation results on a data sheet using the code given above.

8. Calculate the proportionate number of circular plots for each snow condition.

9. Calculate the total acreage for each snow condition class by applying these proportional values to the total area of the watershed.

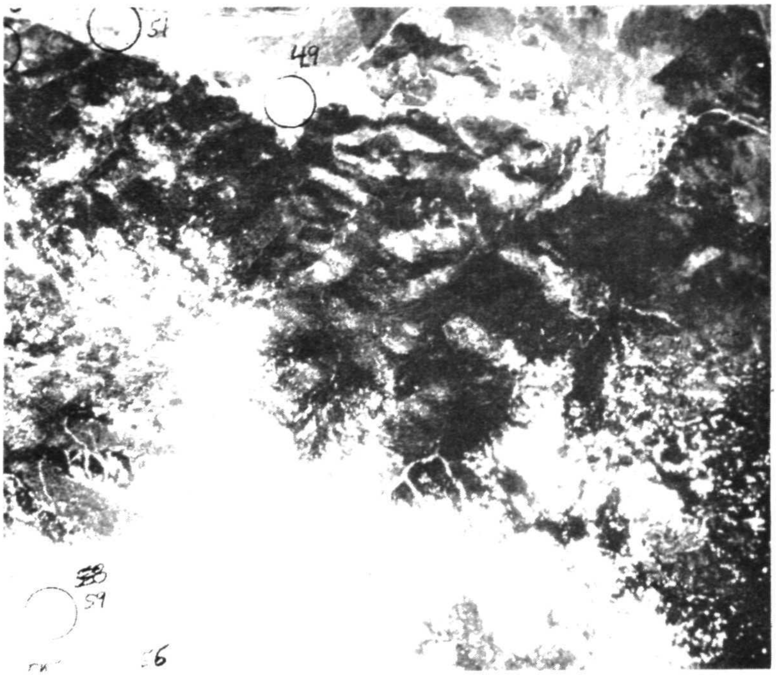
10. Adjust downward the acreage estimate for each of the condition classes relating to boundaries (i.e., codes 2, 3, and 4) by multiplying the gross acreage values by the appropriate value of percent of ground covered by snow (i.e., midpoint of percent cover class).

11. Sum the adjusted acreage estimates for the entire watershed.

Test Results and Conclusions

The interpretation technique described above and the image interpretation key were applied to the 4600 acre Mill Creek Watershed located in the very center of the Feather River region. A group of ten interpreters studied the interpretation key and then, while working independently, estimated the areal extent of snow for the Mill Creek Watershed using 70 mm U-2 photography taken on March 28, 1972. Figure 4.13 illustrates the U-2 photography (top) and the annotated topographic map with grid overlay (bottom) which were employed during this experiment. An example data sheet compiled by one of the interpreters is shown in Figure 4.14. Note that for the Mill Creek Watershed, 115 sample points, each approximately 5 acres in size, were interpreted in terms of percent snow cover. The subsequent calculations resulting in a estimate of snow cover are given at the bottom of Figure 4.14. A summary table showing the range of estimates of percent snow cover for all 115 points is presented in Table 4.7.

As indicated in Table 4.7, which shows the range in interpretation estimates by ten interpreters, the interpreters were unable to agree on the snow cover classification for many of the points. A Chi-Square analysis of these data indicated that the individual interpreter's classification distributions were independent of each other, indicating a wide variety of



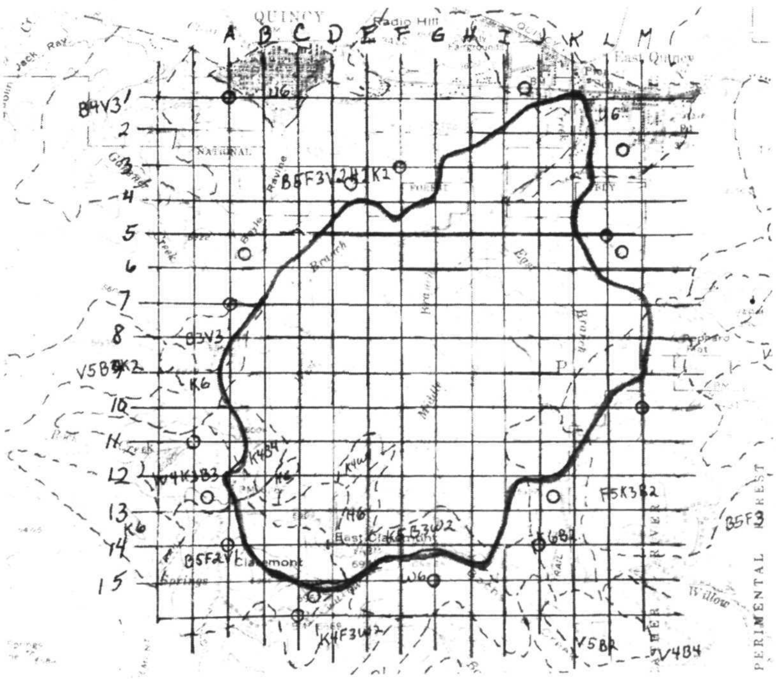


Figure 4.13. The enlarged U-2 photograph (top), taken on March 28, 1972, shows the 4600 acre Mill Creek watershed near Qunicy, California. By employing the topographic map (bottom) annotated with major vegetation/terrain information and correctly positioned in a Zoom Transfer Scope, ten interpreters estimated percent snow cover at each of the 115 grid intersections.

Watershed Mill Creek Imagery U-2

Interpreter DTC March March 28, 1972

	GRID POINTS													SUMMARY				
	A	B	C	D	E	F	G	H	I	J	K	L	M	1	2	3	4	5
1											1			1				
2									1	1	1			3				
3								1	1	1	1			4				
4					1		1	1	1	1	1			6				
5				1	1	1	1	1	1	1	1			8				
6			1	1	1	1	1	1	1	1	1			9				
7		5	2	1	1	1	1	1	1	1	1	1	3	9	1	1		1
8		5	2	1	3	1	1	1	4	1	2	4	4	5	2	1	3	1
9	5	4	2	2	4	3	1	1	2	4	3	5	5	2	3	2	3	3
10		5	5	5	5	2	1	1	3	5	3			2	1	2		5
11		5	5	5	5	2	2	5	5	5	5				2			8
12	5	5	5	5	5	5	5	5	5	5	5							10
13		5	5	5	5	5	5	5	5	5								8
14		5	5	5	5	5	5	5	5									7
15			5	5														2
														49	9	6	6	45

Snow condition #1 - 49/115 x 4600 = 1960
Snow condition #2 - 9/115 x 4600 = 360 x 10% = 36
Snow condition #3 - 6/115 x 4600 = 240 x 35% = 84
Snow condition #4 - 6/115 x 4600 = 240 x 75% = 180
Snow condition #5 - 45/115 x 4600 = 1800 x 100% = 1800

Total snow = 2100 acres

Figure 4.14. Interpretation results derived by each interpreter for the Mill Creek watershed were recorded on data sheets like the one shown here. The ordinate and abscissa grid coordinates shown on the topographic map in Figure 4.13 are given above as numbers 1 through 15 and letters A through M, respectively. Note that an estimate of percent snow cover was made for each of the 115 grid points (i.e., 1 = no snow, 2 = 0-20 percent snow, 3 = 20-50 percent snow, 4 = 50-100 percent snow and 5 = 100 percent snow). The calculations predicting total snow cover for the watershed are given at the bottom.

TABLE 4.7. RANGE OF INTERPRETATION ESTIMATES OF PERCENT SNOW COVER FOR 115 SAMPLE POINTS (TEN INTERPRETERS). MILL CREEK WATERSHED, MARCH 28, 1972

	A	B	C	D	E	F	G	H	I	J	K	L	M
1											0-10		
2									0	0	0-10		
3								0	0	0	0-10		
4						0	0-10	0	0	0	0		
5				0	0	0	0	0	0-10	0-10	0		
6			0-10	0	0	0	0	0	0-10	0-10	0-10		
7		0-100	0-35	0-75	0-75	0-10	0-10	0-10	0-75	0-75	0-10	0-75	0-75
8		10-100	0-75	0-75	10-100	0-35	0-35	0-10	0-75	0-75	0-75	10-100	0-100
9	75-100	35-100	10-100	0-100	10-100	10-100	0-35	0-75	10-100	0-100	10-100	10-100	75-100
10		75-100	75-100	75-100	10-100	0-100	0-75	0-75	10-100	75-100	10-100		
11		75-100	75-100	75-100	35-100	0-100	0-100	35-100	75-100	75-100	35-100		
12	100	100	100	75-100	75-100	35-100	35-100	75-100	35-100	100			
13		100	100	100	100	100	100	100	100				
14		100	100	100	100	100	100	100					
15		100	100										

Note: The ordinate and abscissa gird coordinates shown on the topographic map in Figure 4.13 are given above as numbers 1 through 15 and letters A through M, respectively.

classifications for many of the points on the image. For each point where complete agreement by all ten interpreters occurred, the point classification was either 0 percent or 100 percent snow cover. Thus, as was predicted, the areas exhibiting show boundary conditions were the most difficult to interpret, and in this case the snowpack boundary passed through the middle of the watershed.

Some of the variation in the classifications is due, of course, to the variation in interpreter skill and knowledge about snow conditions. In one case, one of the most inexperienced interpreters made an obvious error by classifying points 1K and 2K as 10 percent snow cover, because that person confused the light-toned urban area with areas of low density snow cover. However, at most of those points where the interpreters disagreed on the amount of snow present, one or more of the following three situations prevailed:

1. In areas of low density vegetation cover, the interpreter would classify exposed soil as patchy snow or vice versa (e.g., points 7D, 7E, and 7L).

2. The quantity of snow present in boundary areas between vegetation types was difficult to determine on the imagery because snow conditions in the surrounding areas were not always indicative of the condition at the point in question (7B, 9J).

3. Photo interpreters had difficulty in determining how far down stream channels the snow line extended (10G).

All of the interpreters felt, however, that given more training and experience with this kind of an interpretation problem, they would be more

confident and more accurate in predicting snow cover along the boundary area. In addition, each interpreter agreed that the technique involving the use of the Zoom Transfer Scope greatly facilitated the interpretation task. Thus, it is anticipated that the newly developed interpretation technique applied to the Mill Creek Watershed could be employed with ERTS-1 imagery for the entire Feather River Watershed when estimating areal extent of snow cover.

4.2.2 Analysis Within the Northern Coastal Zone

4.2.2.1 Introduction

In recent years, a greal deal of public attention has been focused on the coastal zone of California. With population, income and leisure time on the increase, coastal lands have come under mounting pressure for development for human habitation and for use by recreationists and as a place for more intensive use and development of natural resources in an industrial sense.

It is generally felt that the expected intensification of resource use in the north coast region will lead to serious environmental problems in the absence of wise land use planning. Due in no small part to this concern, and after many years of study and debate, the people of California enacted the Coastal Zone Conservation Act in November, 1972. This act created a California Coastal Zone Commission which will use $5 million of state money and $15 million of federal money (Coastal Zone Management Act - 1972) to generate a land use plan (California Coastal Zone Conservation Plan) for the preservation, restoration, orderly development, and enhancement of California's "coastal zone". The "coastal zone" covered

by this act is defined as that land and water area "extending seaward to the outer limit of the state's jurisdiction, and extending inland to the highest elevation of the nearest coastal mountain range". It is hoped that through the provisions of this act many of the problems which have occurred in more highly developed areas of the state can be avoided in the north coastal zone, because intelligent planning of land use can occur only <u>before</u> intensive land use activities become widespread.

One prerequisite of intelligent land use planning of any region is a detailed and comprehensive knowledge as to the environment of the area in terms of its effect on potential resource management and use. In the north coastal area, one urgently needed type of information is an integrated inventory and evaluation of the physical and biological characteristics of the region as they relate to suitability for various types of land use. In this regard the Forestry Remote Sensing Laboratory of the University of California is conducting a NASA-sponsored remote sensing study of the usefulness of aircraft and spacecraft imagery for preparing integrated resource inventories and for monitoring significant changes in the physical and biological environment of the North Coast of California.

The North Coast Test Site dealt with in this study encompasses the entire area (10,362 square miles) within the five coastal counties of northern California between San Francisco's Golden Gate and the Oregon border, viz., Marin, Sonoma, Mendocino, Humboldt, and Del Norte. The overall test site is rather rural in nature, with a large part of the area in an essentially undeveloped state. Four hundred eighteen of California's 1,072 coastline miles are located along the west edge of this test site. This

stretch of ocean coast is rated by many as the most beautiful in the state and it is where a large portion of the developmental pressure is being directed. Within the test site most studies are being performed in two intensive study sites. The northern study site encompasses a swath of coastal land extending inland some 20-25 miles from Cape Mendocino to the Humboldt-Del Norte County line. The southern intensive test site includes the area encompassed by Sonoma and Marin Counties. Several studies have been conducted in other areas within the test site, while some have been conducted outside but adjacent to the test site. They are reported in this section because their findings are applicable to the resources of the North Coast Test Site.

4.2.2.2 <u>Objectives</u>

The primary purpose of this investigation is to evaluate the usefulness of remote sensing data in providing general land use planning information pertaining to the north coast of California, as defined by the North Coast Test Site. It is anticipated, however, that in the process much information of direct benefit to resource managers and developers within the area will be derived. More specifically, the objectives are: (1) to determine the level of accuracy, the time and the costs to prepare a land use inventory using human interpreters; (2) to determine the level of accuracy and detail for classifying significant land use categories using automatic interpretation techniques; (3) to use quantitative test procedures to determine which bands, dates, and combination of bands and dates of imagery obtained by the ERTS-1 system provide the optimum data base for generating land use maps; (4) to determine which of the various

biological and physical features that exhibit change over time can be discriminated and monitored; and (5) to determine which remote sensing techniques (e.g., change detection techniques; image enhancement; density slicing; densichron analysis; and Transfer Scope viewing) will be needed to extract useful information from the ERTS-1 and supporting high altitude aircraft data.

A significant undertaking required before these objectives can be attained involves an enumeration of those parameters which are of particular importance to environmental planners in determining the potential of an area in terms of land use, be it natural resource utilization, open space preservation, urban expansion, or industrial development. Interaction between the FRSL and planners currently involved in the formulation of long range land use plans for the coastal region of California is necessary for this undertaking.

The remainder of this report on the North Coast Test Site describes the research activities which have been, are, or will be conducted to satisfy the objectives of the remote sensing project. They include: (a) compilation of a classification scheme which includes the environmental parameters of particular importance to land use planners; (b) human analysis of aircraft and spacecraft data in two intensive study sites; (c) development of a resource information system in a timbered area adjacent to the North Coast Test Site; (d) analysis of a large burned-over area in the chapparal-woodland type and also adjacent to the North Coast Test Site; and (e) analysis of coastal and river water.

4.2.2.3 North Coast Environmental Planning and Classification Data

One major objective of the North Coast Study is to determine the

feasibility of using the information obtained from remote sensing as an aid to regional environmental planners for planning the orderly development of this area. In order to accomplish this task, it is necessary to identify the inputs which are or could be utilized in the planning process, and then assign relative weights to these inputs in terms of their significance to the planners' objectives. The next requirement is to compare this weighted list of desired inputs with a list of that information which physically can be derived through the analysis of remote sensing data. This second list should be weighted according to the cost or time associated with generating the desired information from the remote sensing data and also by the level of accuracy attainable. Only in this manner, can an "optimum" remote sensing system be developed to assist regional planning. The steps taken to determine the information requirements of regional planners are presented in the remainder of this section.

In an area as large and diverse as the North Coast Test Site, it is difficult to identify any one regional planning agency which has objectives and data requirements which would satisfy all north coast planners' needs. The agency which most closely met these criteria in the north coast area was a temporary state government body set up from within the Department of Navigation & Ocean Development (the Interagency Council for Ocean Resources) which cooperated with all other state resource agencies and also county planners in the creation of the California Comprehensive Ocean Area Plan (COAP). The major shortcoming of the data requirements outlined under this Plan resulted from the fact that the plan dealt exclusively with a narrow and sometimes arbitrarily defined area immediately adjacent to the

beach or coast itself (essentially as specified in the Coastal Zone Conservation Act passed after COAP was completed). In order to meet planning needs within the broader North Coast Test Site, additional data requirements must be defined. In order to insure the most comprehensive list of desirable environmental data possible (applicable throughout the north coast), a number of documents were reviewed. The primary sources used to develop the list of information needs were:

The California Comprehensive Ocean Area Plan (COAP), 1972. State of California, Department of Navigation & Ocean Development, Interagency Council for Ocean Resources.

Supplement to COAP, 1972. State of California, Department of Navigation & Ocean Development, Interagency Council for Ocean Resources.

California Coastline -- Preservation and Recreation Plan, 1971. California Department of Parks and Recreation (in cooperation with COAP).

Fish and Wildlife in the Marine and Coastal Zone, 1971. California Department of Fish and Game (in cooperation with COAP).

Ocean Coastline Study, 1970. Association of Bay Area Governments (ABAG).

Can the Last Place Last, Preserving the Environmental Quality of Marin, 1971. Marin County Planning Department.

Mendocino County General Plan, Planning Division, Department of Public Works.

Recreation Plan, 1985, Sonoma County Planning Department.

Design with Nature, 1969. Ian L. McHarg.

Natural Vegetation and Land Use Classfications, 1972. Dr. J. Estes, et al, Geography Department, UC Santa Barbara.

The above list of references is by no means exhaustive of the literature reviewed by the FRSL or the large number of recent publications which deal with coastal problems.

TABLE 4.8. PARAMETERS OF IMPORTANCE TO ENVIRONMENTAL PLANNERS FOR DETERMINING THE POTENTIAL OF AN AREA IN TERMS OF LAND USE

I. Site Characteristics or Physical Attributes

- A. Landforms
  - Beaches (rocky and sandy)
  - Cliffs, steep slopes, some land slides
  - Dunes
  - Island
  - Mud flat
  - Sea stack, rookery
  - Spit, bar
  - Playas
  - Marine terraces
  - Swamp
- B. Geology
  - Parent material -- 9 geologic types on coast of California
  - Faults -- monitor seismologic activity -- rank areas for hazard
  - Aquifers
  - Aquifer recharge areas
  - Oil or gas fields, other mineral deposits
- C. Pedology
  - Soil type } stability (erodibility, compressibility)
  - Soil drainage } stability (erodibility, compressibility)
- D. Physiography
  - Elevation, slope (steepness and form), aspect
  - Intervisibility
  - Exposure (shoreline): protected → exposed
  - Access (shoreline): plains, low terrace, high terrace, hills
  - Drainage net or pattern (delineate watershed)
  - Flood plain
- E. Water Bodies
  - Open water -- estuary
  - Open water -- lagoon
  - Lakes and ponds
    - permanent
    - ephemeral
  - Reservoirs
    - classify by type of dam } hazard ranking
    - classify by proximity to seismologic areas } hazard ranking
  - Rivers and streams (stream order)
  - Tidal marsh
  - Tidal flat
  - Coves, bays
  - Deep water access
  - Springs
- F. Marine Features
  - Kelp beds
  - Sediment plumes
  - Water clarity
  - Water temperature
  - Waves and currents
  - Depth
  - Reefs
  - Wildlife areas (abalone, fish, seals, otters, birds, etc.)
- G. Primary Vegetation
  - Species composition
  - Density
    - stems/acre
    - percent crown closure
  - Timber volumes

Examples of Primary Vegetation Classification

Natural Vegetation (COAP)		Biotic Communities (Calif. Dept. of Parks & Rec.)	Land & Marine Ecology (ABAG)
Barren	Nb	1. Redwood Forest	Vegetative Cover:
Coastal Forest	Nc	2. N. Coast Coniferous Forest	1. Coniferous Forest
Redwood Forest	Nf	3. Maritime Pine Forest	2. Hardwood Forest
Grassland	Ng	4. Mixed Evergreen Forest	3. Grass and Forbs
Hardwood	Nh	5. N. Coast Scrub	4. Chaparral & Mtn. Brush
Woodland Grass	Nj	6. Chaparral	5. Cultivated & Pasture
Kelp	Nk	7. N. Coast Grasslands	6. Barren
Marsh (salt)	Nm	8. Coastal Strand	7. Urban
Marsh (fresh)	Nn	9. Freshwater Marsh	Ecological Features:
Riparian	Nr	10. Coastal Salt Marsh	Extent of Abalone
Coastal Sage	Ns	11. Sandy Intertidal Zone	Extent of Bishop Pine
Cut-Over Redwood	Nw	12. Rocky Intertidal Zone	Cormorant Nesting Areas
Other	Nz	13. Nearshore Zone	Sea Lion Rocks
		14. Urban	Gull Nesting Area
		15. Agriculture	Heron Rookery
			Eel Grass Beds
			Important Fishing Areas
			Clam Beds

- H. Other Features or Phenomena
  - Vegetation oriented
    - burned over areas
    - clear cuts
      - by tractor
      - by cable
    - insect and pathogen infestations
    - smog damage
    - fuel hazard for fires
    - windthrow along cutting boundaries or within selective logging areas
  - Land oriented
    - landslides
    - stream aggradation and other changing stream conditions (e.g., amount of shade for water)
    - areas of tidal inundation likelihood (e.g., from hurricanes)
  - Recreation oriented
    - historic/archeologic sites
    - unique sites or situations of high scenic appeal
  - Wildlife oriented
    - monitor wildlife herd size
    - identify wildlife herd range and changes in range over time
  - Climatic oriented
    - snowfall, fog occurrence (spatially and over time)
  - Pollution oriented
    - air -- smoke, dust
    - water -- effluents, sediment loads, thermal
    - noise -- industrial, vehicular (proximity to likely sources of noise)
    - aesthetic -- clear cuts, cut and fill areas, urban blight

II. Land Use

- A. Urban and Industrial
  - Residential
    - density (families/net acre)
      - 0-1 very low
      - 1-5 low
      - 5-9 low-medium
      - 9-29 medium-high
  - Industrial
    - manufacturing and warehousing
    - utility installations
    - extractive (mines, quarries, etc.)
  - Military
    - bases and camps
  - Commercial
    - business centers
    - urban recreation (bowling alleys, stadiums, race tracks)
  - Transportation
    - highways and roads
    - airfields
    - harbor facilities
    - railroads
    - canals
  - Institutions
    - universities and hospitals
- B. Open Space
  - Agricultural
    - intensive -- cultivated or irrigated } could easily be expanded to include crop types, crop condition, etc.
    - less intensive -- grazing } could easily be expanded to include crop types, crop condition, etc.
  - Commercial forest
  - "Non-commercial forest" (wildland)
  - Regional recreation (golf courses, ski areas, parks)
  - Other non-developed areas

III. Land Ownership and Land Values

After the literature review had been completed a list of data requirements was compiled (see Table 4.8). The next step, after compiling this list, was to acquire "feedback" from the environmental planning agencies which deal with the problems created by the developmental demands being made on the North Coast Test Site. The type of feedback desired included the suitability of the parameters themselves (additions and/or deletions), the scales and frequency of data acquisition desired for each item or group, and the relative value of each input item or input class. To date, only Marin County (one of the more advanced counties in terms of planning) has responded to the listings in Table 4.8. The replies by Ruth Corwin, Marin County Environmental Coordinator, and Ellis Gans, Marin County Planning Staff, were both informative and enlightening.

They grouped their information needs into "countywide" and "sub-area" levels. The Marin planners listed the optimum image scales for obtaining both countywide level and sub-area level types of information as follows:

<u>optimum image scales for countywide information:</u>

1" = 2000' to 8000' (1/24,000 - 1/96,000),

where 1" = 2000' for display map of a corridor

1" = 4000' as a handy format for entire county

1" = 8000' as the suggested format for county atlas

<u>optimum image scales for sub-area level information:</u>

1" = 1000' to 3000' (1/12,000 - 1/36,000)

Concern was expressed over the costs of enlarging remote sensing imagery in order to be of maximum value, but these workers recognized the capability of using remote sensing tools to interpret at once scale and record at another.

The Marin planners also provided a listing of what they considered basic information for a county atlas. This included topography (e.g., slope categories and drainage patterns), soil type (e.g., stability and erodibility), vegetation types (e.g., timber, grass, brush, and marine), and geology (e.g., landslide and fault hazard areas). Also mentioned were intervisibility (determination of area visible from any given vantage point) and the location of rare and/or endangered biotic communities or species.

A list of environmental parameters was prepared which the Marin County planners felt should be monitored either periodically (mostly on an annual basis) or on short notice. The parameters which could be evaluated by remote sensing included: Land use by slope classes; amount and type of development on unstable soil or subject to flood or fault hazard; annual amount of agriculture gone out of production; annual increase in developed land by category (e.g., residential, commerical, etc.); and special areas within Marin County of importance to environmental quality (e.g., Bolinas Lagoon). On the whole, Marin County planners felt that "the compilation of data (in Table 4.8) looks good", in terms of the information that could be used to improve their county plans.

Having generated a complete listing of the important environmental parameters in the north coast, we recognize that it remains for image interpreters and remote sensing data analysts, to determine the feasibility of providing information regarding those parameters in the desired format, within the desired time frame and for the desired cost. It is envisaged that the list of environmental parameters will serve as the basis for a

workable classification scheme and as the basis for determining which resource can be identified on the different types of aircraft and spacecraft imagery. Interfacing a desirable classification scheme for the remote sensing data with the information requirements of regional planners is one of the major tasks involved in remote sensing system development.

4.2.2.4 Manual Analysis of ERTS-1 and Supporting Aircraft Data in the Southern Intensive Study Area

Description of Study Area: Sonoma and Marin Counties

Sonoma and Marin counties comprise the southern intensive study area within the North Coast Test Site, and occupy an area of approximately 1,344,000 acres (2100 square miles) immediately north of and adjoining San Francisco Bay, California. This area is complex in both physiography and land use and includes considerable forest, range, pasture, and agriculture (vineyards, apples and feed crops) land. It is dissected by two major river systems, and it fronts on both the Pacific Ocean and San Francisco Bay. The impact of population pressure is felt in this area as increased urbanization and transportation networks spread along the north bay shore of Marin County and the interior valleys of Sonoma County. Increasing pressure among user groups for more land preserves or more development (in single units, large developments, large private holders or state owned land), makes accurate land use inventory, monitoring, and planning a necessity.

For this reporting period, analysis of remote sensing data was limited to imagery of Sonoma County (see Figure 4.14) because cloud free ERTS-1

Figure 4.14. This ERTS-1 color composite image (July 27, 1972) of Sonoma County, California illustrates the delineation and classification of homogeneous appearing areas. The text contains explanations and analyses of 23 land use vegetation/terrain type classifications applied to this region of the North Coast Test Site.

imagery of a northern intensive study area was not available until the October 27 pass. Seven ground truth cells of approximately four square miles, representing differing land use, were set out. Ground photographs were taken in conjunction with ERTS-1 overflights (July 7 and 11 and August 31) for verification between interpretation on the satellite imagery and actual ground conditions. To complete the sampling, some excellent U-2 imagery (scale 1:130,000 and 1:445,700) of the area was obtained by the NASA/Ames facility on July 5, 1972 and October 6, 1972.

The objectives for analyzing ERTS-1 and high altitude aircraft data are to determine (1) what environmental or land use parameters can be delineated and classified on ERTS-1 imagery, and (2) to what degree identification of these areas is possible on ERTS-1 alone and with the aid of supporting aircraft and ground truth data.

Material Examined

ERTS-1 imagery available for evaluation and interpretation during this study period included:

7/27/72	generally clear, except along coast
8/13/72; 8/14/72	clear
9/1/72	20 percent cloud cover
9/19/72	50 percent cloud cover, scattered cumulus
10/7/72	90 percent cloud cover
10/25/72	clear - positive transparencies very dense
11/12/72	30 percent cloud cover
11/30 72	40 percent cloud cover

The July 27, 1972 ERTS-1 imagery of Sonoma County was selected for the

initial interpretation for the following reasons: (1) good quality imagery was available for interpretation and for combining into a color composite image (2) Sonoma County was virtually cloud free, (3) ground data were collected near the time of the ERTS-1 overpass, the (4) a U-2 high altitude flight (72-110) occurred close to the date of the ERTS-1 overpass.

In addition, 70 mm and 9 x 9 inch color infrared aerial photographs were obtained by the U-2 aircraft on July 5 and October 6, 1972. The July imagery was of very high quality and covered the eastern portion of Sonoma County. The aerial photography taken on October 6 provided coverage of the western half of the county. This high altitude photography (65,000 feet) provided the data against which the delineations and classifications made on ERTS-1 imagery from July were compared.

Procedures

The first step taken during the analysis of the ERTS-1 imagery of Sonoma County was to review the classification schemes described in the previous section. This review revealed that many of the informational requirements of regional planners could not be satisfied with the level of information extractable from ERTS-1 imagery. Their needs would be better served by high altitude photography of higher resolution (as provided by the U-2 aircraft). It was felt, however, that generalized land use and vegetation/terrain maps could be prepared from the satellite imagery. These generalized maps could be of considerable value in less developed areas requiring a more general classification scheme.

The second step in the analysis was to delineate the homogeneous areas visible on the ERTS-1 imagery. For this purpose, black-and-white ERTS-1

imagery from MSS bands 4, 5, and 7, was delineated based upon the tone, texture, and location of features. A diazochrome color composite, simulating a false-color infrared image, was prepared using three MSS bands; the composite was made by superimposing band 4 reproduced on yellow diazochrome film, band 5 reproduced on magenta diazochrome film, and band 7 reproduced on cyan diazochrome film. Then using color, texture, and location of features as clues, homogeneous areas were delineated and classified on the color composite.

The third step was to compare the delineations made on the ERTS-1 color composite with the high altitude photos taken on July 5 and October 6. To facilitate this comparison, the delineations made on the ERTS-1 color composite were transferred directly to the U-2 high altitude imagery by means of a Zoom Transfer Scope. Finally, the high altitude color infrared photographs were interpreted to verify the delineations and classifications made on the ERTS-1 color composite and to establish the true identity of many of the units delineated.

Results of the Analysis of the ERTS-1 Color Composite

Figure 4.14 shows the ERTS-1 color composite with the homogeneous units delineated. A description of each of these mapped areas appears in Table 4.9. These descriptions are based primarily upon analysis of high altitude photography and ground data, rather than on interpretation of the ERTS-1 composite. The analysis of the ERTS-1 composite revealed that only a limited number of categories could be accurately or consistently identified, although the delineations, themselves, coincide quite closely with different land and environmental categories.

In general, healthy vegetation categories could be identified and differentiated from dry or unhealthy vegetation types. That is, forest and shrubland types could be distinguished from dry rangeland types. Differences within the healthy vegetation category attributed to plant density were readily apparent and delineated. Major river systems, specific urban complexes and agricultural land (see Table 4.9) were also among the broad categories which could be identified directly on the ERTS-1 color composite. With the aid of high altitude U-2 photography and a limited amount of ground data, all the categories (map units) delineated on the ERTS color composite were identified.

The 23 separate descriptions fall into eight general categories: forest, agriculture, grassland and grassland/woodland, chaparral or scrub, marshland, riparian, urban, and barren. As such, they conform to many of the general categories which appear in the classification schemes produced by COAP, ABAG and the State Parks system. The amount of detail required by these schemes, which varies, is often met by the sub-classfications -- as mapped on the ERTS-1 color composite image. For more accurate or refined vegetation typing, including species identification and determination of land use practices, high resolution imagery, accompanied by some sampling on the ground is essential.

Figure 4.15 shows three examples of U-2 imagery provided by NASA/Ames. The delineations appearing on these photos are those transferred from the ERTS-1 color composite image by means of the Zoom Transfer Scope. Note that these delineations are easily compared with the actual ground features seen on the U-2 photos. It should be apparent that there is good

TABLE 4.9. DESCRIPTION OF MAP UNITS DELINEATED ON THE ERTS-1 COLOR COMPOSITE IMAGE

1. Forest: greater than 95% vegetated (based on proportion of ground area obscured by vegetation in the vertical view); little bare soil and/or rock outcrops, mountainous terrain. Species include canyon live oak, California black oak, bigleaf maple, madrone, red alder (California white oak and blue oak restricted to eastern county).

2. Forest: greater than 98% vegetated, little or no bare soil or rock outcrops, restricted to northern coastal hills. Species include a mixture of hardwoods and young conifers: bigleaf maple, madrone, bishop pine, tan-oak, Douglas fir, red alder, redwood.

3. Forest/Grassland: up to 10% open grassland and/or rock outcrops, mountainous terrain. Species composition similar to 1 above, increased open grassland being the major difference.

4. Forest/Grassland: 50-60% open grassland, in general occupying drier inland sites and mountainous terrain. Species composition Douglas fir, madrone, tan-oak, chinquapin.

5. Forest/Grassland: Grassland up to 20% total area, northern county, mountainous terrain. Some commercial conifers including Douglas fir, sugar pine; other species include tan-oak, chinquapin and oaks.

6. Forest/Grassland: Occupies inland mountainous terrain. Species composition similar to 4 above, but with less open grassland (less than 20%).

7. Forest: 90% commercial conifers; grassland less than 10%. Some coastal influence affects species composition (e.g., of bishop pine, Douglas fir, and redwood).

8. Agriculture: young orchard area along stream margin.

9. Agriculture: mixed agriculture on river valley flood plain, generally small fields, including dry and irrigated pasture, alfalfa.

10. Agriculture: large fields formed on reclaimed land, mature or harvested in July, thereby appearing bright white.

11. Agriculture: smaller fields planted to feed grains, scattered small orchards and residences.

12. Agriculture: Napa Valley vineyards.

13. Agriculture: primarily apple orchards located on river terraces.

14. Grassland/Brush: coastal chaparral type.

15. Grassland/Pasture: associated with interior foothills, dairy farms predominate.

16. Grassland/Pasture: similar to 15 but having less dairy farms, slightly drier sites than 15.

17. Grassland/Woodland: interior foothills, annual grassland are predominant on slopes while oaks dominate in drainages and on hilltops.

18. Oak/Chaparral: oak more prevalent than brush types. Species include California white oak, California black oak, Oregon white oak, canyon live oak, California live oak.

19. Chaparral/Oak: chaparral-hardwoods in approximately equal proportions. Species similar to 18.

20. Marsh: saltwater marsh. Species include pickleweed.

21. Urban:

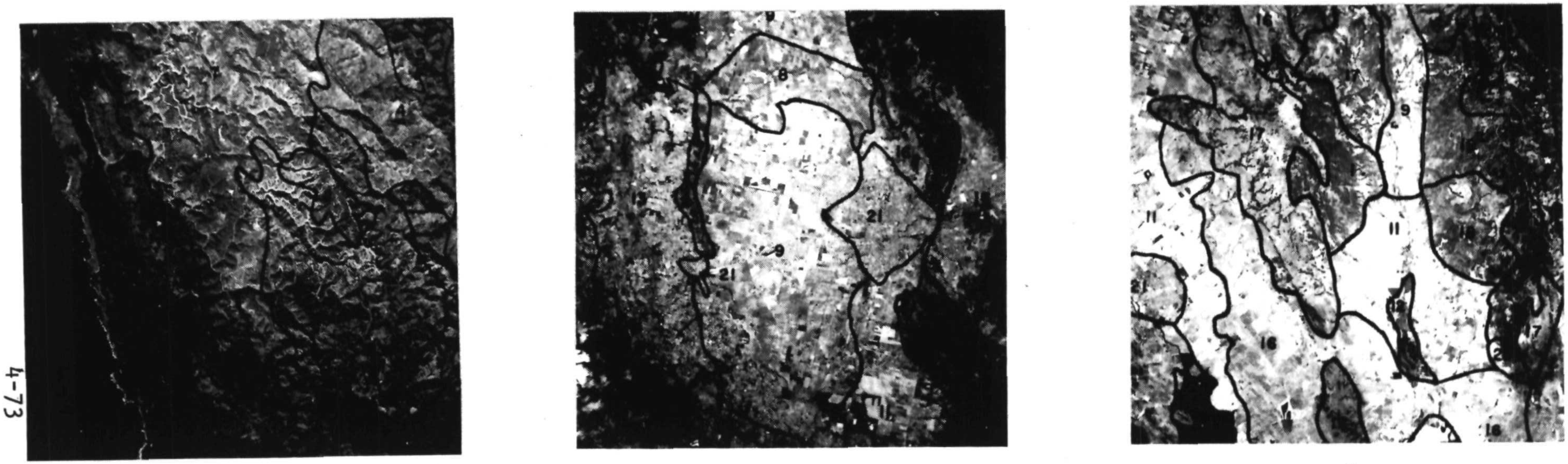
22. Area of Little Vegetation: serpentine soil, burned area, limited extent.

23. Bottomland: along river, riparian vegetation present, limited extent.

correlation between the delineations of land use and vegetation/terrain types made from the ERTS-1 color composite image and the features seen on the aerial photos. Accurate identification for the majority of the mapped units, however, was possible only with the aid of the higher resolution aerial photographs. For a few of the mapped units, large scale photographs and ground data were required to provide accurate identification. As can be seen on Figure 4.15-A, there is good coincidence between the ERTS-1 and high altitude images for the mapped areas of forest. However, in order to accurately identify the various categories of forest land (types 1-7 in Table 4.9) high resolution images or ground data were required. The sub-classifications within the forest class are based mainly on varying proportions of open space and woody vegetation. Forest categories (1-7), however, could not be accurately differentiated from other vegetation types such as riparian (23) and shrub-chaparral (14, 18, 19) on the ERTS-1 composite image.

Agriculture categories (8-13), however, could be identified and differentiated from other categories on the ERTS-1 image. A comparison of types 9 and 11 (See Figure 4.15-B, C) suggests that subtle differences between agricultural land categories are related to field size. In addition, the relative amount of irrigated pasture in an agricultural area could be detected on ERTS-1 imagery. The stratification and identification of different agricultural types could be improved by mapping at a more desirable seasonal state using a multidate approach. These aspects will be investigated and reported upon in fu ure reports.

In Figure 4.15-C, the transfer of data from ERTS-1 to the U-2 photo



A B C

Figure 4.15. These U-2 false-color infrared photographs of Sonoma County illustrate the technique used to evaluate interpretation results derived from ERTS-1 imagery. Delineations and classifications made on the ERTS-1 imagery have been accurately plotted onto the U-2 photographs using a Zoom Transfer Scope. Consequently, boundary placement and type of identification are easily evaluated when positioned on the high definition U-2 photos. Note that photo "A" illustrates mainly forest classifications. Photo "B" shows the cities of Santa Rosa and Petaluma surrounded primarily by agriculture classifications. Additional agricultural classifications surrounded by grassland-shrub-woodland types are illustrated in photo "C". The classification symbols appearing on these photos are explained in Table 4.9.

TABLE 4.10. IDENTIFICATION OF MAPPED UNITS
ON ERTS-1 AND LARGER SCALE IMAGERY TAKEN DURING ONE SEASONAL STATE

Categories from Table 1 Delineated on ERTS-1 Color Composite Image	Categories Identifiable on an ERTS-1 Image. (Single Date)	Categories Requiring U-2 or Larger Scale Imagery for Identification
Forest		X
1		X
2		X
3		X
4		X
5		X
6		X
7		X
Agriculture	X	
8		X
9		X
10		X
11		X
12		X
13		X
Grassland & Grassland/ Woodland	X	
15	X	
16	X	
17		X
Shrub-Chaparral		X
14		X
18		X
19		X
Marsh		X
20		X
Urban		
21	X	
Barren		
22		X
Riparian		
23		X

shows that grassland and grassland/woodland types can be accurately mapped. Interpretation of the U-2 photo shows that the differences in the ERTS classifications were due to relative density differences in the grassland (15), grassland/oak (16), and brush and oak (17) types. The ERTS-1 image appears to have adequate detail for the differentiation of types 15 and 16. The July seasonal state is excellent for distinguishing grassland, now dry, from healthy, green vegetation types.

Figures 4.15-B and 4.15-C show the capabilities of ERTS-1 for allowing discrimination of shrub-chaparral types. While these categories can be mapped separately, they tend to be easily confused with forest types. Therefore, higher resolution imagery is required to consistently differentiate these categories.

Marshland (seen on Figure 4.15-C), is easily delineated on the ERTS-1 imagery and can be classified separately from all other categories. Its proximity to the estuary makes the identification of this category possible, although absolute verification is possible only with the aid of the U-2 photography.

Several urban centers can be seen on Figures 4.15-B and 4.15-C. The perimeters of the urbanized areas blend into adjoining dry grassland and pasture and are difficult to map accurately on ERTS-1 imagery. The urban centers, however, are visible as separate entities and can be identified as "urban" on the ERTS-1 imagery. The July ERTS-1 imagery is not the optimum one for classifying urban areas which are bordered by dry grassland and dry land agriculture -- later in the year these adjoining areas will turn green and will contrast sharply with urban areas on images taken in the red band (e.g., MSS no. 5).

The category of barren areas (22) refers to those areas which appear to be devoid of vegetation or which do not conform in appearance to other natural categories. One example in the northern part of Sonoma County is a region of serpentine soil which has a sparse covering of vegetation. Another example of barren land is an area in the southern part of the county. It can be seen in Figure 4.15-C and appears to be a brush/oak mixture which was burned by a wildfire sometime after the U-2 imagery was taken on July 7 and before the ERTS-1 imagery was taken on July 27.

The riparian vegetation mapped on Figure 4.15-B occurs along a stream course and though accurately mapped on ERTS-1, it could not be consistently identified in other areas on this type of imagery alone.

Table 4.10 summarizes the findings of the comparative analysis of the ERTS-1 color composite image and the U-2 photography for those categories which were initially mapped on the ERTS-1 color composite image. It should be apparent from this table that many wildland and cultural features (categories) can be accurately <u>delineated</u> on an ERTS-1 image, but only a few can be accurately <u>identified</u>. Most of the mapped categories could be identified using U-2 photography. These analyses also revealed that certain categories could be identified because of their seasonal appearance in July. It is recognized that still other categories will be identifiable because of their seasonal appearance at other dates.

4.2.2.5 Automatic Analysis of Aircraft Data at Boggs Mountain

Development of a resource <u>information system</u> for both agricultural and wildland resource applications has been underway at the FRSL for the past two years. The Boggs Mountain project was undertaken as a case study

for timber management purposes. The ultimate goal of this project is to supply forest management personnel with current information about changing timber resources. To obtain a realistic understanding of typical, periodically occurring timber management decisions and related information requirements, "representative" managers are being interviewed. It is hoped that through this interaction the system capabilities will be directed toward practical problem areas and that the user's needs will serve as a natural starting point rather than a "limitation" of the system.

Spatial Reference System

Resource information systems are often grouped according to their spatial reference system, i.e., their way of referring to information by spatial criteria. The systems can be placed in two categories: Resource information can be stored (1) in "cellular" form (a grid of small rectangular cells) or (2) as a polygon. The latter form is preferred, where possible, because of its smaller storage space requirements.

The coordinate system used now in local applications such as the Boggs Mountain project is a rectangular Cartesian system.

An additional aspect of a spatial reference system is that when the source material is aerial photography it can be transformed from perspective projection to orthogonal. Two approaches to this problem are the camera lucida principle (e.g., through the use of a transfer scope) and the orthophoto principle. Neither method is compatible with the FRSL automatic image processing system without additional work and cost inputs. As an intermediate solution, a single high altitude (68,000 feet) aerial photo was used as a resource data source for the Boggs Mountain project.

Because of the altitude, the small amount of radial displacement on the photo was not a factor in the calculations in this particular application.

Boggs Mountain Overlays Obtained Directly Through Remote Sensing

The high altitude color infrared photo transparency (scale 1:120,000, Figure 4.16) of the Boggs Mountain State Forest in northern California was digitized using the scanning microdensitometer -- and these data were used as input for the CALSCAN program. CALSCAN separates and classifies individual or combined reflectance features into discrete classes and prints out a map of these classes.

The photo area was digitized into 352,000 samples points by the scanner. This corresponds to 6,040 acres or 59 sample points of spectral data per acre. In addition, every scanned point was measured three times, using a different color transmitting filter each time in order to measure the amount of reflectance represented by the red, green and blue emulsions of the film.

A printout of the digitized data was produced in which each symbol represents a range of optical densities. On this grey-scale rendition, the X, Y coordinates of representative vegetation classes from the forest were determined and these groupings of points were subsequently used to train the statistical discriminant program. The six classes in the study were: Bare soil, California Black Oak, Ponderosa pine, Douglas fir (old growth), and brush. The data were classified by the maximum likelihood discriminant algorithm, and the resultant color display is shown in Figure 4.18.

The automatic classification of wildland areas using spectral data is

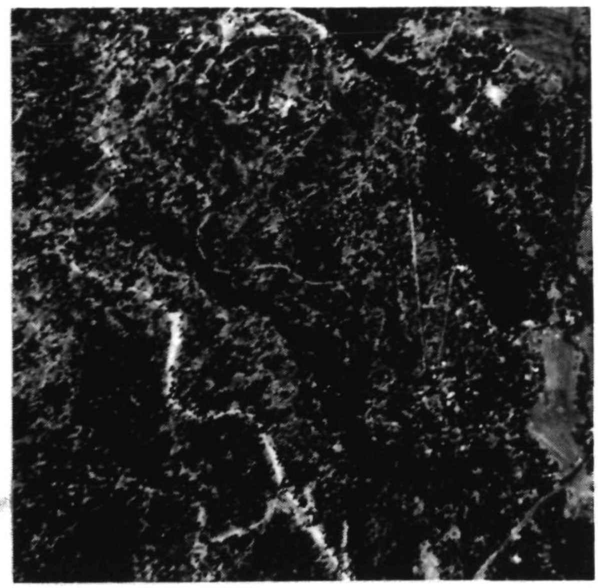
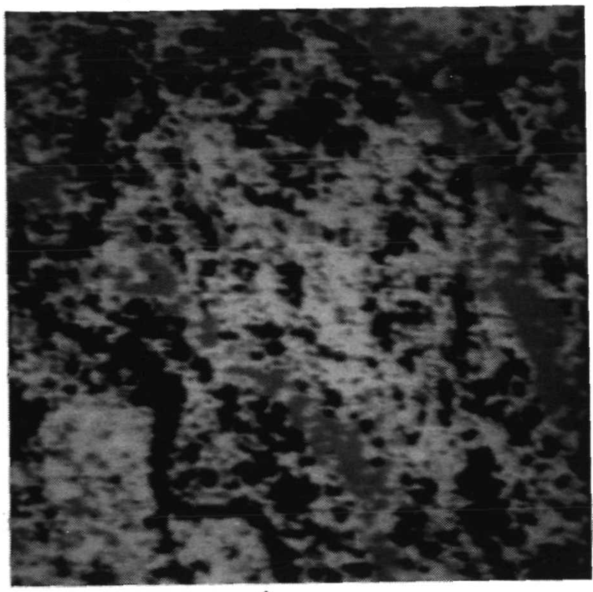
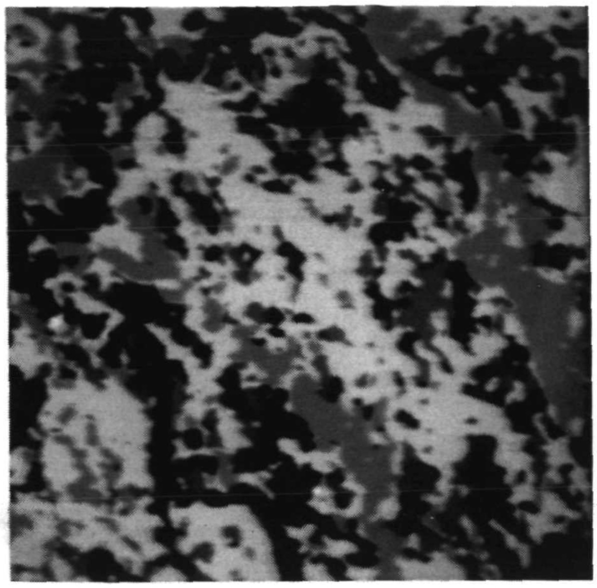


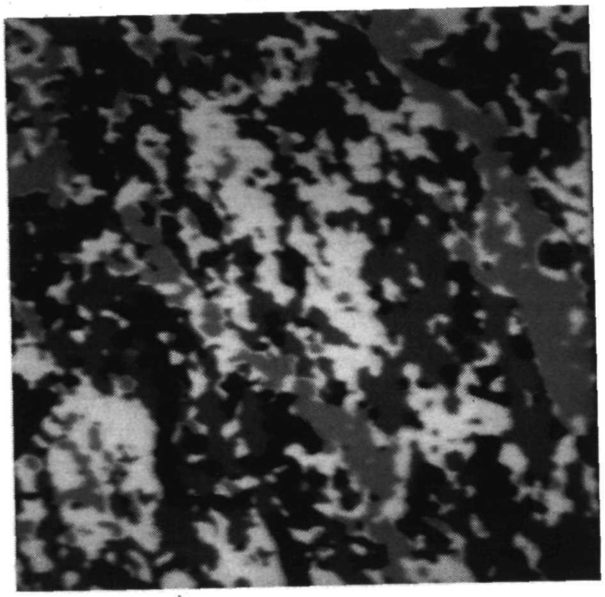
Figure 4.16. Copy of the color infrared transparency of the Boggs Mountain study are at a scale of 1:120,000. This was scanned three times by the FRSL scanning microdensitometer using color separation filters to generate three sets of spectral feature data for CALSCAN analysis.



A



B



Douglas Fir = green
Ponderosa Pine = red
Brush = yellow
Bare Soil = black
Black Oak = blue

Figure 4.18A. The raw results of the discriminant analysis of the Boggs Mountain data photographed from the color CRT show little resemblance to the original photo or the "ground truth" because of errors in the spectral signature caused by differing illumination and edge effects due to data points falling on boundaries between types.

C

Figure 4.18B. The display of the reclassified results was generated by considering the spatial distribution of neighboring points. Note that the Ponderosa Pine does not appear in this display. This is caused by the low percentage of ground cover of this species even in fully stocked stands on this site.

Figure 4.18C. This display is the result of a reclassification based on spatial information in which Ponderosa Pine was given a relative weight of 1.4. This operation resulted in the most favorable comparison with existing ground data.

made possible by the non-homogeneous nature of plant communities. Two problems are, however, that the species of interest, such as Ponderosa pine in the study, does not always cover the majority of the ground area in the site and that the discrete scanned points do not always fall completely within a specific species type. Therefore, the resulting density levels are an integration of spectral information from more than one species. When these data are used in the classifier the results are usually not meaningful. The probability that a point represents a single species of interest is determined by many factors which include the effective area of integration of the spot on the ground, the spacing between spots, the surface area covered by homogeneous blocks of the species, and the total percent cover of the species. To solve these problems, an algorithm has been developed which increases the accuracy of species delineation by weighting those that do not have a high percentage photographic cover to create a representation which corresponds to the accepted view of that species' growth potential.

The "weight-by-neighbors" clustering algorithm looks not only at each individual point, but also takes into consideration the eight surrounding points comprising a 3 x 3 matrix. For example, if the following is the 3 x 3 matrix for the point of reference, 0, then point 0 (in the center position) would be reclassed as "X" because a plurality of the points are

$$\begin{pmatrix} X & X & X \\ X & 0 & X \\ X & X & X \end{pmatrix}$$

classed as "X". In the event of a tie, the decision is arbitrarily given to the first of the tied classes under consideration, unless one of the tied points was the center point, in which case the decision would be given to the center

point. The result of this equal weighting is shown in Figure 4.18B (however, the species does not cover the site completely).

When for mapping purposes it is desirable to have the areas where a species occurs above some minimum level mapped as one type, an unequal weighting is applied to each point in the class. Because of the non-homogeneity of the Ponderosa pine type, the results of the "weight-by-neighbors" program were analyzed to determine the optimum weighting. Because 1.9 appears to be the maximum weight one would assign to a type under normal circumstances, the "weight-by-neighbors" routine was repeated assigning weights of 1.9, 1.8, 1.7, 1.6, 1.5, 1.4, 1.3, 1.2 and 1.1 to Ponderosa pine while holding the other classes at a weight of 1.0.

All 440 x 800 points were plotted using the weight of 1.9 for Ponderosa pine, but for the sake of economy, only the first 220 x 200 points were plotted for the Ponderosa pine weights of 1.8, 1.7, 1.6, 1.5, 1.4, 1.3, 1.2 and 1.1. The results are summarized in Table 4.11. Using weight 1.4 (Figure 4.18C) roads and many bare spots show clearly, but when weight 1.5 was used, much of the area occupied by roads and bare spots was lost to the Ponderosa pine. Hence, weight 1.4 appears to have the greatest value from this timber-typing point of view. Because a sharp contrast was apparent between the 1.4 weight and the 1.5 weight reclassification results, a 220 x 383 map was generated using the weight-by-neighbors routine and assigning a weight of 1.5 to Ponderosa pine, a weight of 1.2 to Bare Soil and a weight of 1.0 to all other classes. A weight greater than 1.0 was assigned to Bare Soil because when a weight of 1.5 was given to Ponderosa pine while leaving all else 1.0, the Bare Soil (especially roads) disappeared to an undesirable extent.

TABLE 4.11. CLASSIFICATION SUMMARY FOR ENTIRE MAP

Weight Given to Ponderosa Pine	Percent Classed as: Doug-fir	Black Oak	Pon. Pine	Bare Soil	Brush	Total No. of Points Classified
1.8	6.43	3.08	76.82	8.02	5.65	44,000
1.7	6.43	3.08	76.82	8.02	5.65	44,000
1.6	8.68	4.10	61.28	15.51	10.42	44,000
*1.5	8.68	4.10	61.28	15.51	10.42	44,000*
*1.4	10.37	5.14	41.15	24.69	18.63	44,000*
1.3	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1.2	12.56	5.26	18.95	33.85	29.37	44,000
1.1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1.0	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

re-iteration:

*1.5	17.65	3.07	45.15	7.29	26.83	347,600*
*1.4	21.11	3.50	25.68	12.15	37.45	347,600*

The timber typing of the area was also done by using conventional human photo interpretation techniques. Because of the 1:120,000 scale of the transparency, the partitioning into types was fairly superficial. It will enable, however, an interesting comparison between the performances of automatic and human timber type interpretation methods in this particular application.

Overlays Obtained from Existing Sources

The characteristic feature of the "MAPIT" data bank, as introduced in last year's report, is the simultaneous storing of a finite number of resource overlays geared to a common spatial reference system. Each overlay typically consists of the spatial distribution of one resource attribute. In addition to the timber-type overlay discussed above, the following overlays, obtained from existing maps, were digitized in the scanner and stored in tape files:

a. Linear Features. Out of various classes of linear features (ridges, creeks, etc.), only roads were of interest to us in this application. Others may easily be added later if the user survey indicates sufficient interest in them. The road network was obtained from USGS topographic maps.

b. Vegetation-Soil. The California Cooperative Vegetation-Soil Survey covered the Boggs Mountain area in 1951-1955. Despite the age of the map, it was expected to give adequate information about the soil series and site class distribution of the area. Knowledge of soils is important in management decisions such as assigning certain species to the correct sites, fighting erosion, and choosing between harvesting methods.

c. Geology. Rock types were obtained from a Geological Map of California published by the California Department of Natural Resources, Division of Mines and Geology (1963). Two major rock types appear on Boggs Mountain: Cretaceous rocks (undifferentiated) in the northeast slopes and Andesitic flows in the southwest slopes. Rock types will be correlated with timber types of the area in an effort to find auxiliary variables to support timber classification.

d. Old Timber Type Map. A timber-type map, drawn by the California Division of Forestry in 1965, was stored in order to compare it with the automatic and human classifications mentioned above. A disturbing factor for the comparison, however, is that the typings are done at different times. This problem can be reduced by inserting growth and cutting data to the old map.

e. Topography. Another feature extracted from the USGS topographic map was the elevation data in the form of contour lines at 200 feet intervals. From this, algorithms will be generated for deriving slopes and aspects. At the moment this approach to "terrain modeling" is regarded as an intermediate one. A more appropriate solution is outlined later this Chapter under the section "Future Proposed Work". Topographic information is used in species allocation, erosion control, logging planning, and estimating the cost of timber stand improvement. Topographic features are also correlated with species distribution and should be useful in automatic timber typing.

Ground Truth Overlays

A general idea of the conditions and the appearance of timber resources

in the Boggs Mountain area was obtained by visiting the area and cruising it in one day. A more systematic ground truth survey was obtained from a live plot survey done by the California Division of Forestry in 1966-67 for timber inventories. A total of 291 one-fifth acre plots were located with 10 chain line spacing and 8 - 12 chain plot spacing. Each plot is described according to the timber type, Dunning's site class and the volume by species. The advantage of this information is its systematic layout and known plot locations, while a drawback is that data are available only from a limited number of points.

The plot-grid overlay was digitized and stored in a tape file as point information. The timber characteristics measured from each plot were punched on cards and merged to the overlay. This overlay provides, to date, the best available check to various timber typings of the area.

Summary

In summary, the Boggs Mountain area is proving to be an ideal wildland resource complex in which to develop and evaluate a computerized information system. A Cartesian spatial reference system is being employed using resource overlays obtained from (1) CALSCAN output (which in some cases has been reclassified using "weight-by-neighbor" clustering) and (2) existing resource maps. The overlays are digitized and stored simultaneously in a data bank called MAPIT. Digitized ground truth data can also be entered into the system for purposes of analysis.

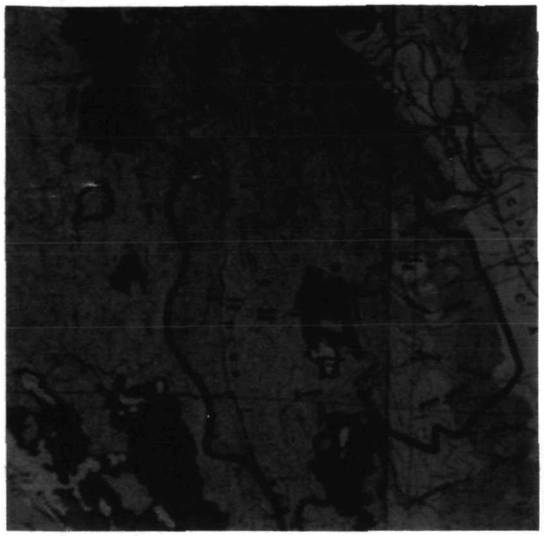
4.2.2.6 Analysis of Wildland Burned Areas on ERTS-1 Imagery

Introduction

The State Division of Forestry in California is required to submit a

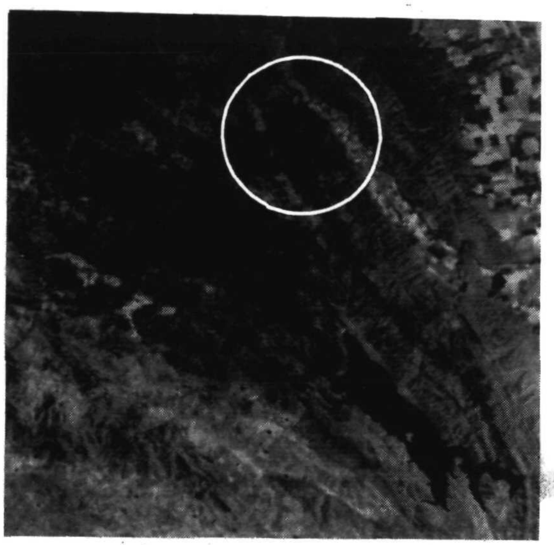
fire map and fire report to the District Office within 10 days after a wildfire has been extinguished (within 30 days to the State office). At present these maps are made by individuals through the process of walking or driving the fire perimeter while drawing boundaries on a topographic map sheet. In the case of very large fires, low flying aircraft or helicopters are employed while an individual draws boundaries by hand directly on a map sheet. These maps typically appear as shown in Figure 4.19-A, and are used almost exclusively for determination of location and acreage burned. This information is needed to determine who should be charged for fire suppression costs (e.g., nearly 50 percent of the Pocket Gulch fire, shown in Figure 4.19-A was on Bureau of Land Management land). In the case of incendiary fires, an acreage estimate is needed to determine the amount of damage (which is added to suppression costs) so that the convicted arsonists can be properly assessed and penalized (e.g., the Fiske Creek fire, also shown in Figure 4.19-A, was maliciously started, and the suspect's trial is currently pending). This section discusses the analysis of fire damage associated with a large wildfire in Northern California adjacent to the North Coast Test Site. A comparison of human and automated interpretation of ERTS-1 imagery for fire damage appraisal is presented.

Perimeter delineations of the Pocket Gulch and Fiske Creek fires were made from an ERTS infrared transparency (MSS band no. 7), acquired on July 27, 1972, approximately 10 days after the suppression of both fires (see Figure 4.19-C). The fire perimeter map was made using the Forestry Remote Sensing Laboratory scanning microdensitometer and computer capabilities, and was compared with the map produced by the California Division of Forestry (CDF) using conventional techniques.

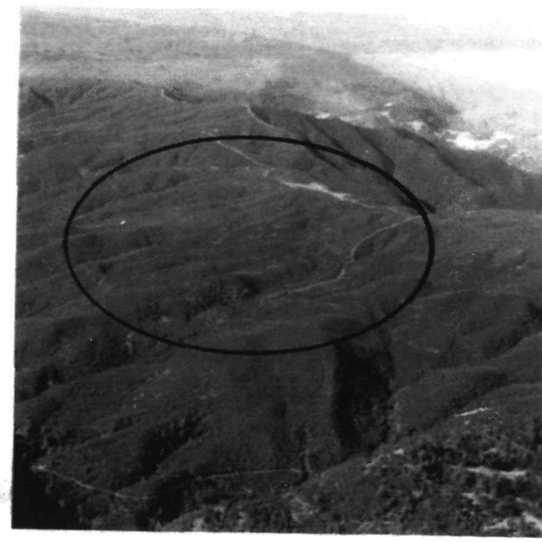


A. (Scale = 1:125,000)

B. (Scale = 1:110,000)



C. (Scale = 1:780,000)



D.

Figure 4.19.

A. California Division of Forestry (CDF) map of Fiske Creek (left) and Pocket Gulch (right) burns. CDF estimates of area burned were 60 acres and 10,340 acres respectively.

B. Map of Fiske Creek and Pocket Gulch burns prepared by the Forestry Remote Sensing Laboratory from a single band black-and white ERTS-1 image, as shown in C. Perimeter detail and information about damage levels within the perimeter are increased here relative to the CDF map in A.

C. Portion of ERTS-1 MSS band 7 image taken on July 27, 1972. Enlargement of this image was used to create map in B.

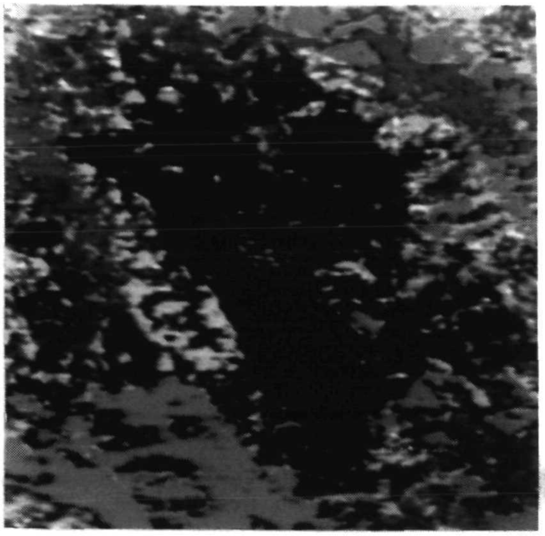
D. Low altitude oblique photo showing the small Fiske Creek burn. Camera is looking towards the south as indicated by annotation 1 on Figure B.

Results and Discussion

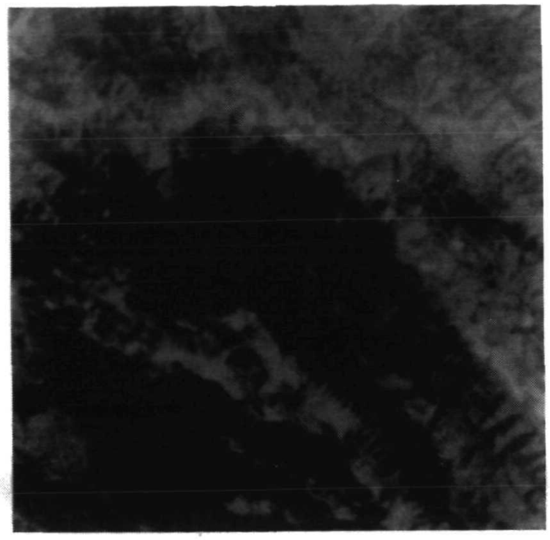
Figure 4.19-B shows the perimeters of the Pocket Gulch and Fiske Creek fires as drawn from the ERTS-1 image and using the FRSL scanner/computer system. The CDF and ERTS-1 maps differ significantly. Estimates of the overall burned area were 10,340 acres and 13,340, respectively. The CDF spent approximately 4 to 8 hours (including flying the fire to draw the map, plus time to use a dot grid for area estimation), or about $500 to map the Pocket Gulch burn. Forestry Remote Sensing Laboratory personnel spent about 25 minutes (after the image was in hand) or about $50 to map the same burn. Low altitude oblique aerial photography (see Figure 4.19-D and Figure 4.20-D) indicates that the fire perimeter map produced by the FRSL is more accurate than that prepared by the CDF. More significant than the improved mapping of the fire perimeter is the additional capabilities provided by ERTS-1 imagery to map the interior of large burned-over areas in detail and to monitor burned areas over time to evaluate vegetative regeneration.

Figure 4.19-B also shows interior delineations which correspond to those areas within the main fire perimeter where little or no fire damage occurred. These delineations were made by a human interpreter using the X-Y coordinate recording scanner and computer facilities at the FRSL.

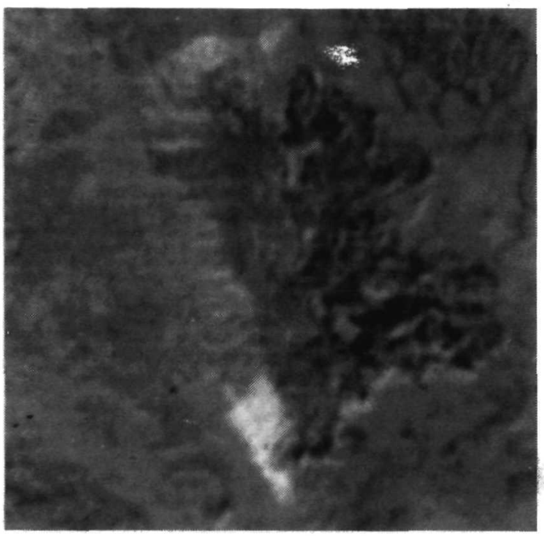
Interior delineations of the burned area can also be made using automated classification techniques. The FRSL's computerized system processed three bands (MSS bands 4, 5 and 7) from ERTS data tapes using its CALSCAN automatic feature classification routine, which then displayed on a color cathode ray tube (CRT) what is seen in Figure 4.20-A. In



A



B (scale = 1:270,000)



C (scale = 1:185,000)

D

Figure 4.20.

A. CRT output from the FRSL's CALSCAN automatic image classification process, using MSS bands 4, 5, and 7 from ERTS-1 data tapes, showing the Fiske Creek and Pocket Gulch burns.

B. NASA color composite, MSS bands 4, 5 and 7, showing the same burns.

C. Change detection enhancement made by the FRSL using the diazochrome composite process showing a control burn (9/15/72-9/18/72) on southwest edge of original Pocket Gulch wild fire (7/17/72).

D. Low altitude oblique showing the unburned grass and orchard "island" within the Pocket Gulch fire perimeter. Camera is looking towards the northwest as indicated by annotation 2 on Figure 4.20B.

addition to the classified image generated by CALSCAN, tabulated statistics are provided for each classified category, enabling ready computation of all relevant areas. A direct comparison of the multiband (4, 5 and 7) color composite in Figure 4.20-B with the multiband classified enhancement in Figure 4.20-A can not be made because the latter shows the result of point by point classification (from magnetic tapes) based on selected training samples whereas the former is an unclassified ERTS-1 color composite image which portrays the wildfire and all the variables of topography, vegetation and degree of burn associated with it. A quantitative comparison of the classified CALSCAN image (Figure 4.20-A) with the human's interpretations (Figure 4.19-B) will be presented in a later report.

Classified maps such as have been discussed here aid in more accurate damage assessment, better planning for salvage logging in timbered areas, improved post-fire revegetation programs (where speed is essential to insure that aerial applications of seed get through loose ashes before a rain), and rapid post-fire fuel hazard evaluation.

The change detection capability of an ERTS-based remote sensing system is illustrated in Figure 4.20-C. The dark green color shows the burned area of the original fires (Pocket Gulch and Fiske Creek, July 17, 1972), and the whitish area signifies a change in the perimeter of the fire as detected by the September 18, 1972 ERTS pass. The multidate enhancement shown in Figure 4.20-C was made using the diazochrome composite process. When the CDF was contacted, it was learned that a private land owner had conducted a control burn on his property (from September 15 - 18) to improve grazing potential, using the west edge of the Pocket Gulch burn as one fuel break. The CDF on-the-ground estimate of the new acreage

burned was 2200 acres. Analysis of the ERTS imagery shows this estimate to be too large. Detection of the new burn is just one example of change which can be detected between passes by the satellite. As revegetation of the burn progresses (both the September 15 control burn and about half of the Pocket Gulch burn have been seeded to grass), it will be monitored and evaluated with the aid of the sequential ERTS-1 data.

The post-fire mapping of burned wildland areas is important for many reasons, and tens of thousands of these fires occur annually across the United States. Consequently, based on these preliminary results, it appears certain that the use of sequentially procured ERTS-1 data, rather than conventional mapping procedures, can provide superior post-fire maps, at more frequent intervals and with greatly reduced manpower requirements and costs.

4.2.2.7 Aerial Survey of Coastal Waters and Rivers of Northern California

Introduction

An aerial survey of the coast was made in order to determine what information could be gained about the flow in rivers and in the ocean along the coast using natural tracers. The natural tracer in this case was suspended sediment. About 1 inch of rain fell during April 11 and 12, 1972, over most of the study area, causing a large amount of sediment to be transported by the streams.

Aerial photographs were taken on April 13 at 1100 - 1300 hours, at altitudes ranging between 400 and 8000 feet above sea level. Two 35 mm cameras were used, one with Ektachrome-X film, the other with Ektachrome

infrared film; photographs were taken simultaneously with the two cameras. Mixing patterns were observed and photographed at the following places:

Golden Gate Bridge

Mouth of Tomales Bay

Coast near the Gualala River mouth

Coast near the Russian River mouth

Austin Creek/Russian River confluence

Carquinez Strait (San Francisco Bay)

The results for the mouth of the Gualala River and for the confluence of Austin Creek and the Russian River were of particular interest and will be discussed in detail.

Mouth of the Gualala River

The Gualala River was discharging a large amount of suspended sediment into the ocean on the day when the photographs were taken. The offshore current was in a southeast direction; the current may have been wind-generated, as a strong (25-30 MPH) northwest wind was blowing. The sediment plume could be detected at least 2 miles from the river mouth. The plume dispersed rapidly in a transverse direction, as shown in Figure 4.21. The edge of the plume furthest from the shore was characterized by a sharp edge. The aerial photography unfortunately yields no information about whether the plume was well mixed vertically or whether it was on the surface only. The density difference between the river water and the ocean would lead one to expect the plume to be on the surface and to mix only very slowly in the vertical.

A comparison of the two photographs in Figure 4.21 shows that, in this

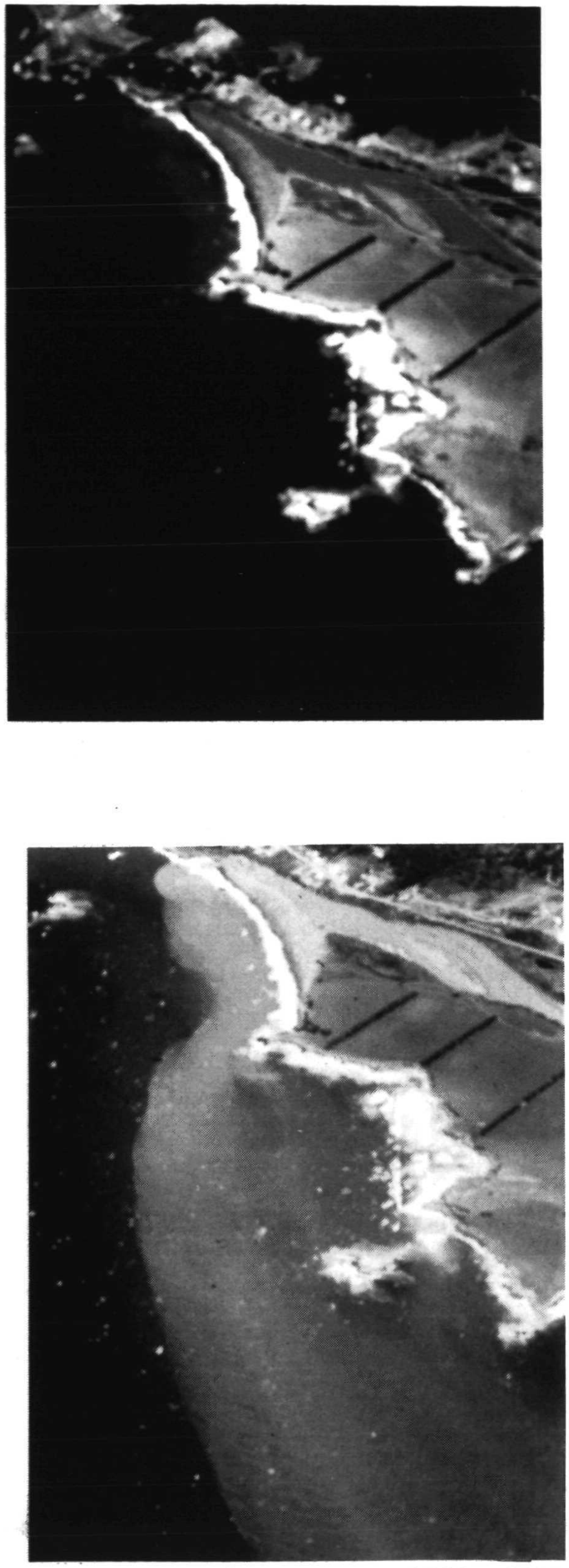


Figure 4.21. Sediment discharging from mouth of Gualala River, California

situation, the Ektachrome X gives higher contrast than the Ektachrome infrared film. This was confirmed in the following way: The original color transparencies of the two photographs of Figure 4.21 were scanned on the microdensitometer to determine the difference in signal between the water with and the water without sediment. Scans were made along lines AA' (see Figure 4.21). The microdensitometer readings are plotted in Figure 4.22. The differences in signal between the sedimented and unsedimented water are shown in the figure. Values for the difference of signal of 160 mV were found for the Ektachrome X film, and 10 mV for the Ektachrome infrared film, showing that the Ektachrome X film gave much better contrast. Similar measurements were made on other photographs (see next section), to verify this conclusion, as the exposure for the color infrared film was slightly too small.

Russian River/Austin Creek Confluence

Photographs of this confluence are shown in Figure 4.23. Scans taken with the microdensitometer along section BB' (see Figure 4.23) are shown in Figure 4.24. The differences in signal between sedimented and unsedimented water are 220 mV for the Ektachrome X film and 135 mV for the Ektachrome infrared film. Thus the best signal is achieved with the Ektachrome X film. Figure 4.24 shows that no improvement in signal is achieved by using a yellow filter in the microdensitometer.

Figure 4.25 shows an interesting circulation pattern. The clear water from Austin Creek enters the Russian River and becomes smaller and smaller in width until it seems to disappear entirely near the edge of the photograph. A small clear patch appears, however, on the opposite side of

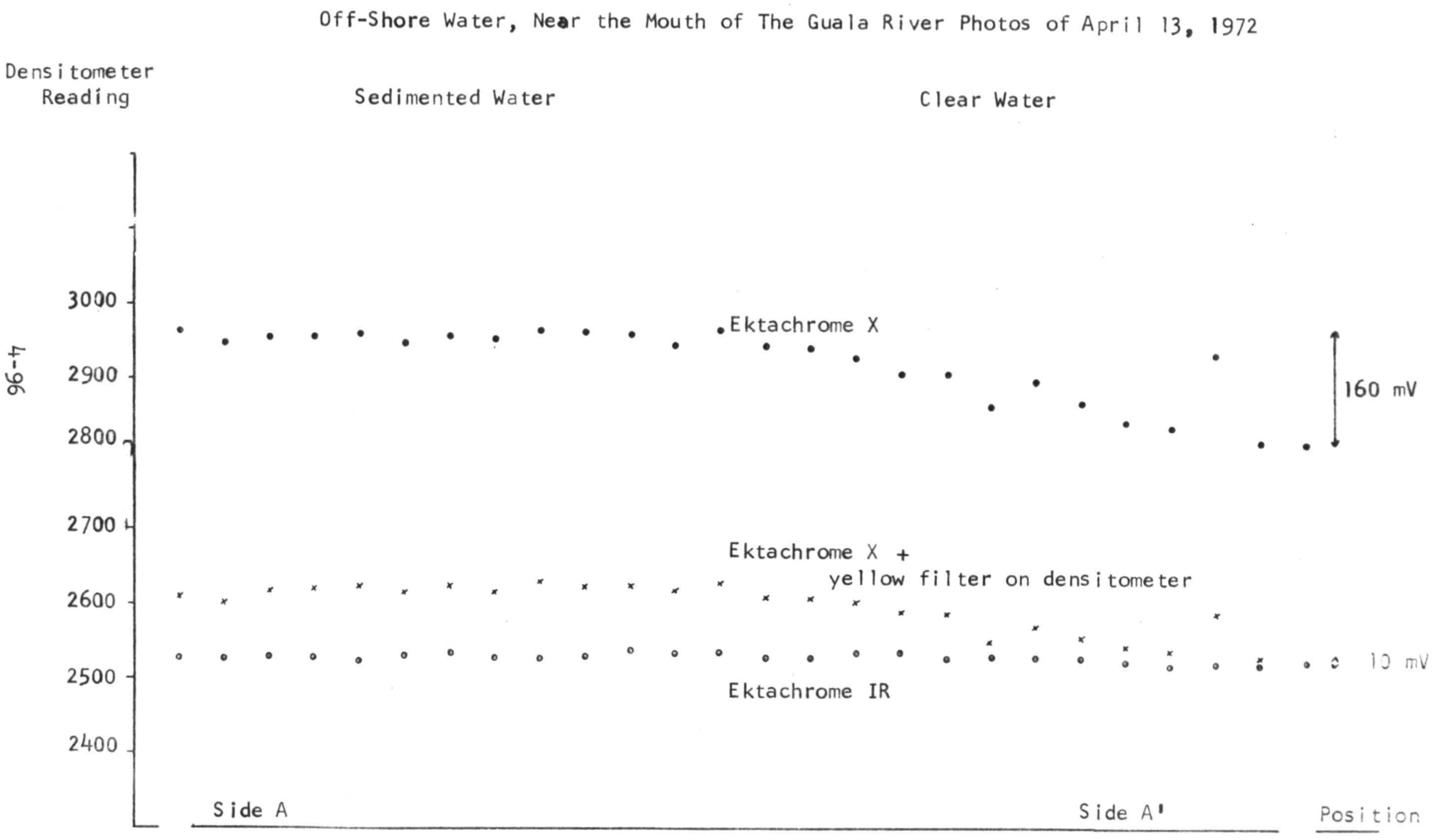


Figure 4.22. Microdensitometer scans of the photographs of Figure 4.21.

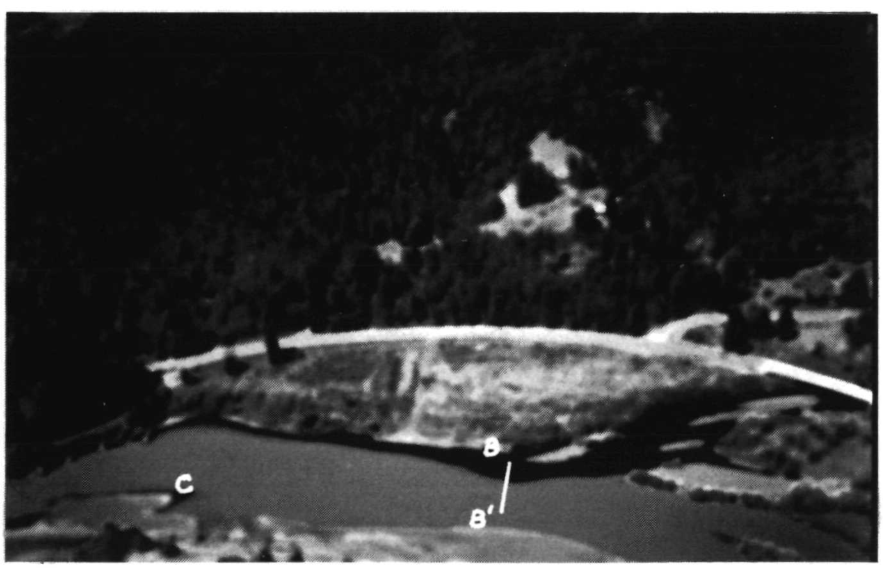


Figure 4.23. Clear water from Austin Creek entering sedimented water in the Russian River.

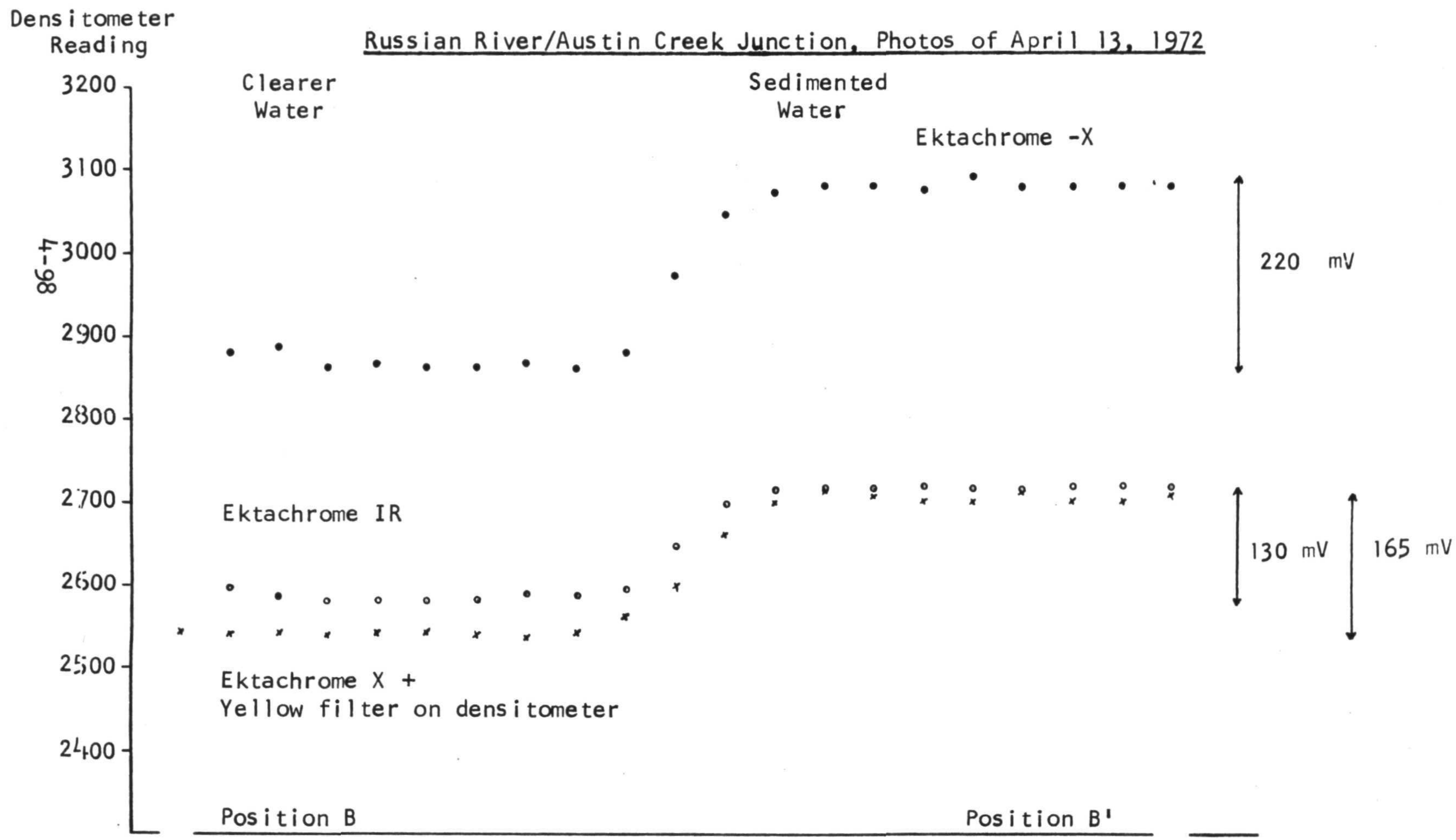
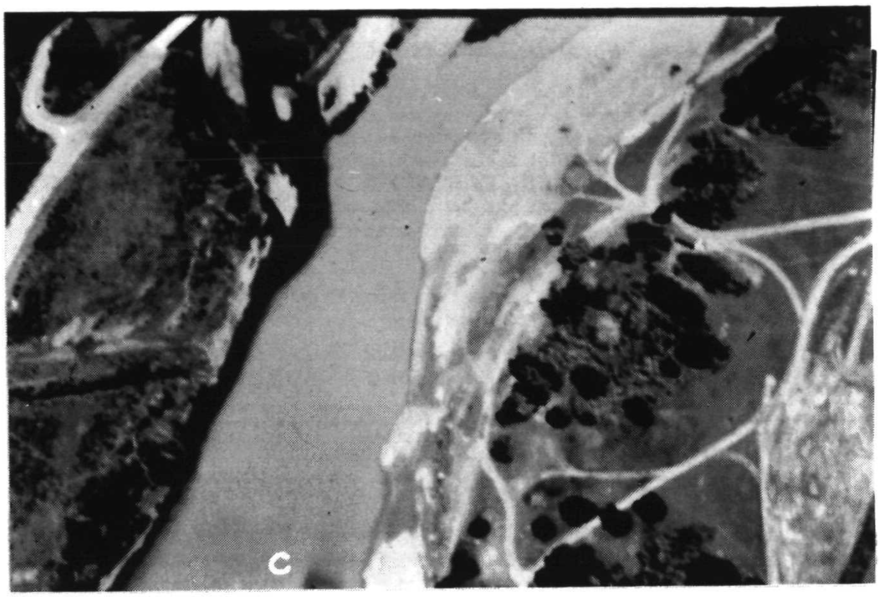


Figure 4.24. Microdensitometer scans of Figure 4.23.



Scale: 0 60 120 180 240 meters

Figure 4.25. Detailed view of mixing pattern, Austin Creek/Russian River confluence.

the river, at position C. One explanation of this phenomenon is to assume that there are secondary currents in the river which cause flow towards the outside of the bend at the surface, and towards the inside of the bend at the bed. If the further assumption is made that the Austin Creek water is slightly denser than the Russian River water (perhaps because of a temperature difference) then the patch of clear water in Figures 4.25 and 4.23 may be explained in the following way: The clear water from Austin Creek sinks to the bottom and is carried under the main flow to appear on the inside bank at position C. The density difference between the two waters would ensure that little mixing occurs during this time.

Dispersion from the East Cliff Sanitation District Outfall

This study was carried out by the State Department of Public Health, as part of their program of investigating the pollution of California beaches. FRSL personnel offered to help in analysis and interpretation of the photographs. These were black-and-white photographs (Kodak Plus-X) taken with a Wratten 25 (red) filter on the camera.

The outfall from part of the city of Santa Cruz discharges sewage with only primary treatment from an outfall at Soquel Point. The outfall is 200 meters from the coast in water having a mean depth of 1 meter (position X, Figure 4.26). High coliform counts had been detected on the beach northeast of the outfall. It was decided to carry out a study with Rhodamine-WT dye, using aerial photography to monitor the dye cloud. The tracer was injected in the sewer about 200 meters above the outfall. Dye was first detected at the outfall at 0754 hours on May 10, 1972. 2.1 liters of 20 percent dye solution were used for the injection. No measurements

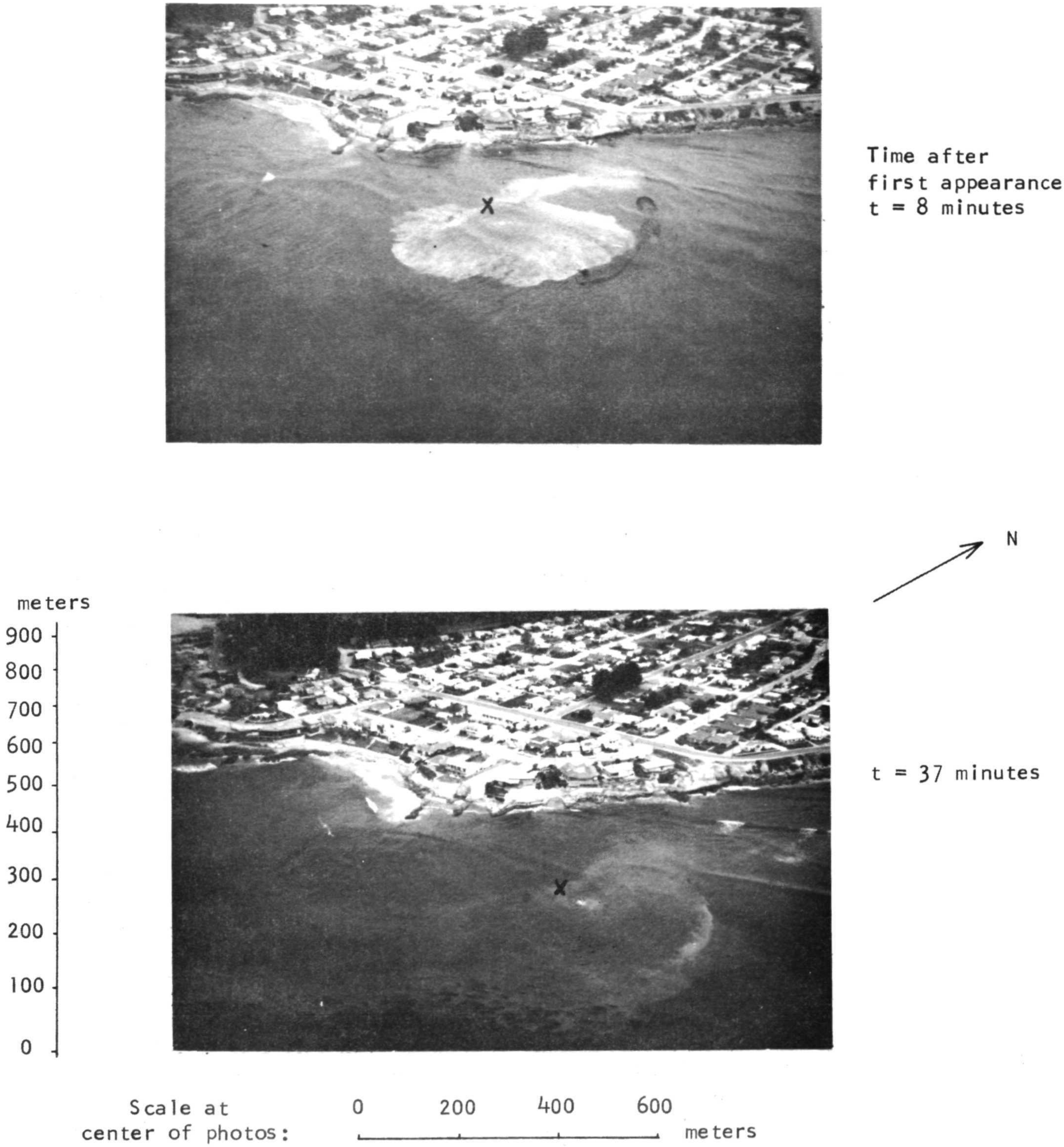


Figure 4.26. Dye distributions following an instantaneous dye injection in the East Cliff Sanitation District outfall, near Santa Cruz, California.

were made of the concentration as the dye left the outfall; however a calculation showed that the mean concentration was 350 mgm/liter. Aerial photographs were taken of the dye cloud at intervals for the next 2-1/2 hours. A swimmer on a surf board collected samples from the ocean for the first 10 minutes after the injection.

Figure 4.26 shows the dye distributions at two times after the injection. The dye is seen to be readily detectable at both times. At the first time, t = 8 mins, the concentration (measured from the samples) was 0.03 mgm/liter. This is about equal to the minimum detectable concentration in laboratory experiments with blue dye.

The results of scanning the two photographs of Figure 4.26 with the microdensitometer are shown in Figures 4.27 and 4.28. The same density splitting was used for both photographs. The extent of the dye cloud may be seen easily in Figure 4.27. In Figure 4.28, where the dye was more dispersed, the area of the cloud is more difficult to determine. The effect of interference by reflection from a breaking wave may be seen in the upper right-hand corner.

The most important conclusions from the photography and the analysis were that:

1. An instantaneous source of pollution diluted itself by an average of 10,000 times within 10 minutes of leaving the outfall under the tidal conditions and wind conditions of the experiment.

2. An extensive bed of kelp, approximately 400 meters offshore, may have restricted the dispersion of sewage from the outfall. The kelp is clearly visible in the lower part of Figure 4.26 (second photograph).

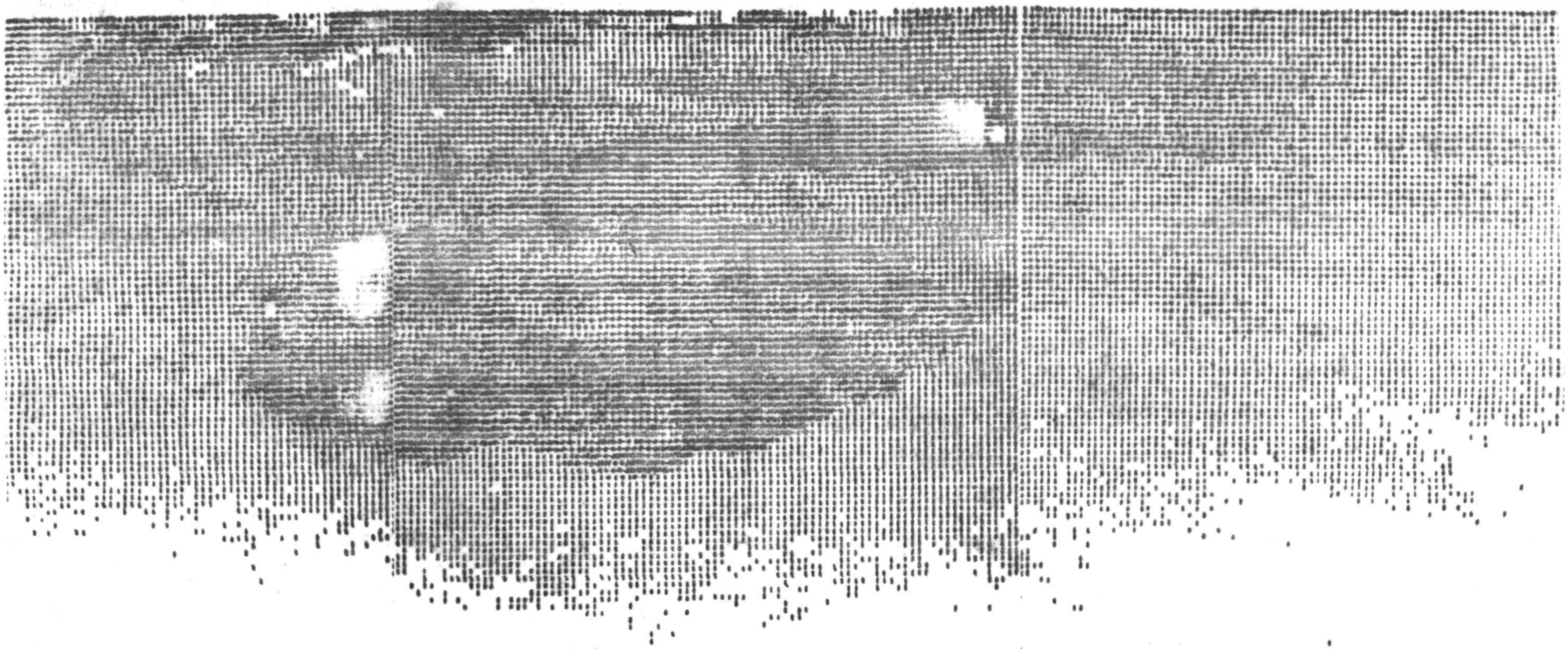


Figure 4.27. Microdensitometer scan of dye distribution at time $t = 8$ mins.

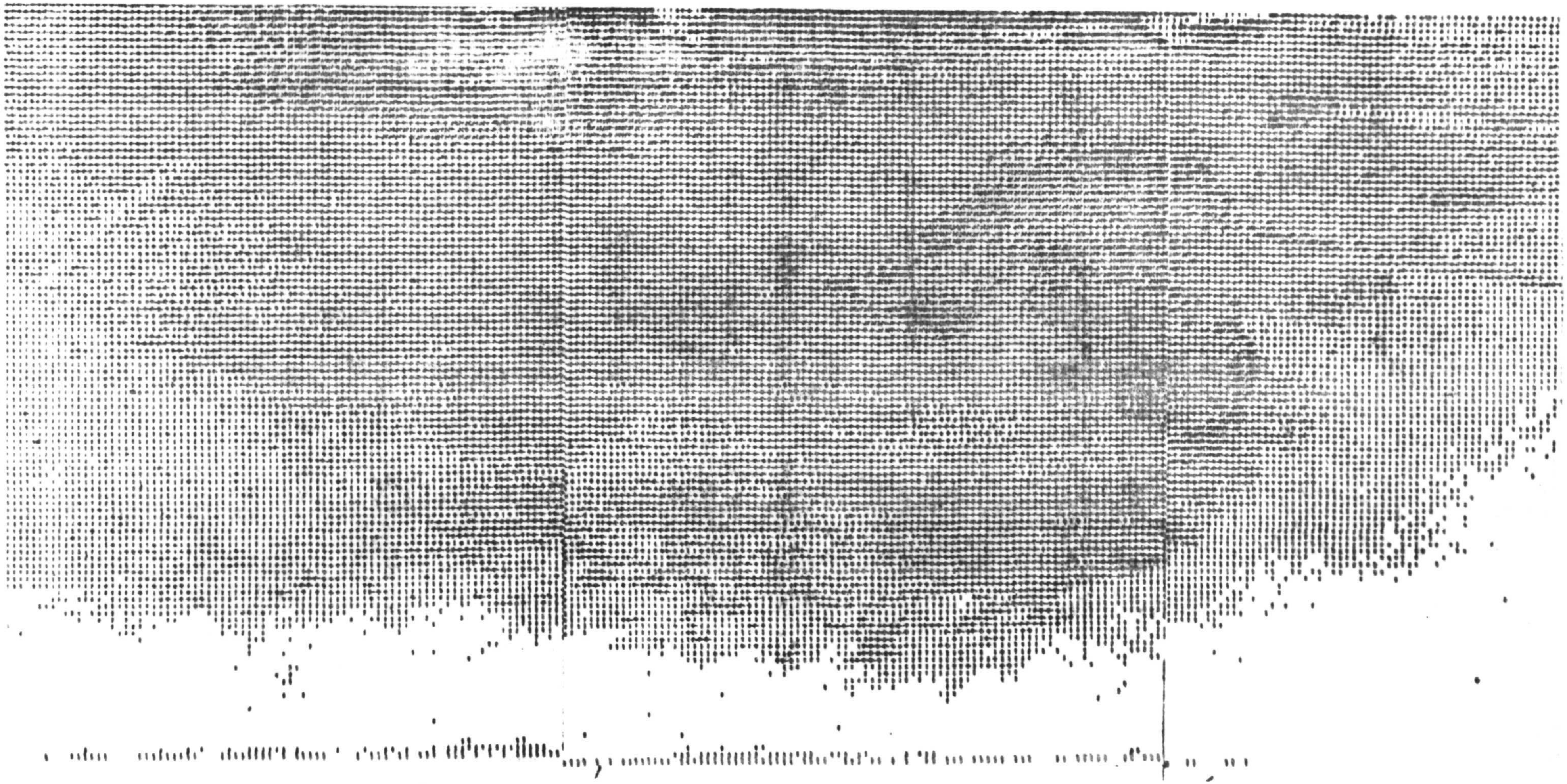


Figure 4.28. Microdensitometer scan of dye distribution at time $t = 37$ mins.

4.3 FUTURE PROPOSED WORK

4.3.1 Analysis Within the Feather River Watershed

4.3.1.1 Vegetation/Terrain Mapping

Future remote sensing research within the Feather River Watershed region will continue to concentrate on demonstrating the application of manual and automatic data analysis. Upon completion of the Feather River regional vegetation/terrain resource map, a major objective will be to compare it with regional ground control maps. This will aid in determining the distributional relationships between vegetation types and soils, lithologic geology, elevation, precipitation and other environmental parameters. This base map will also be suited to aid in the testing of automatically processed ERTS-1 data. In addition to the Davis Lake and Bucks Lake areas which are presently being intensively studied, sites such as the Oroville Reservoir and Lake Almanor sub-regions have been selected for future interpretation testing. Image enhancement techniques which will be applied to ERTS-1 imagery within the sites mentioned will include multidate enhancements using the diazochrome process, new photographic reproduction techniques, and/or other optical or electronic color-combining procedures. Emphasis in future studies of the Feather River region will continue to include quantitative evaluations of results, thus indicating the validity of techniques, methods, and procedures in relation to potentially operational programs.

In addition, the Automatic Image Classification and Data Processing Unit within the Forestry Remote Sensing Laboratory has several hardware and software projects that are now operational and which will be applied

to ERTS-1 imagery taken over the Feather River Watershed region:

Hardware

color display system

Software

ERTS to local reformation

intensive test site data extraction

spectral training data extraction

CALSCAN modification

The color display portion of the FRSL computer facility is also now operational. This display allows the storage and viewing in color of up to 3 bands of digital tape images in common register. As an integral part of the computer system, the display can handle line drawings, ERTS-1 images, CALSCAN output images, and scanner images. The operator has control of the input to each of the color guns in the color TV monitor. Thus, he can display simulated CIR images, real-color or other false-color images. Additional flexibility afforded by this system is demonstrated in Figure 4.29 which shows the Davis Lake area. For example, the image at the top in Figure 4.29-A shows the display of 1/8 of an ERTS-1 frame from computer compatible tape. From this display, intensive test sub-images can be selected and displayed (see middle and bottom photos in Figure 4.29-B,C). After the intensive study areas have been selected, spectral data can be extracted from training areas for use in CALSCAN, and classification results can then be displayed for correlation with ground truth data. The system is also useful for image registration, verification of data, and color enhancement.

In order to reduce the cost of computer processing ERTS-1 data, several

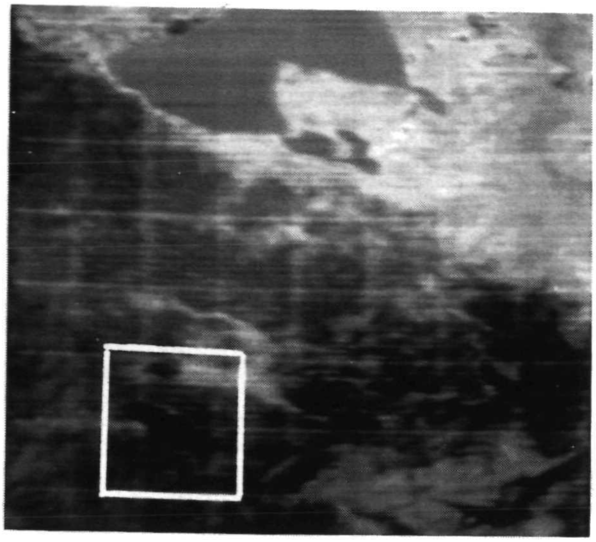


Figure 4.29-A. An 810 horizontal by 1024 vertical array of picture elements (1/8 of an ERTS-1 image) is displayed on the color monitor. Here the red color represents band 7, the green color represents band 5, and the blue color represents band 4 from bulk MSS computer compatible tapes.

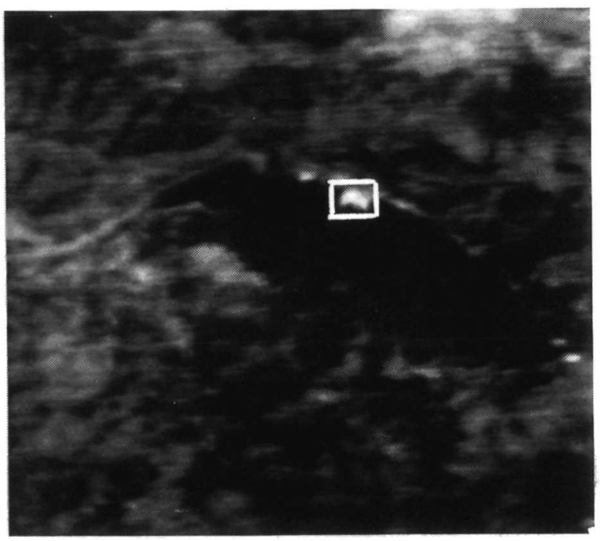


Figure 4.29-B. An intensive test site has been extracted for enhancement and analysis. This 220 by 220 array of picture elements demonstrates the resolution of ERTS-1 digital tape and color enhancement.

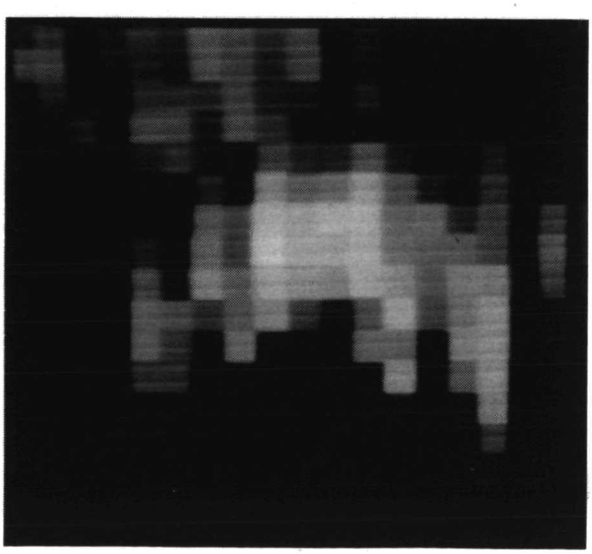


Figure 4.29-C. A 20 by 20 array of picture elements has been extracted from the digital tape used in producing the array in Figure 4.29-B and expanded so that each element is represented by one of the squares. This array can be used to check image registration and spectral information.

pre- and post-classification steps are performed on the Forestry Remote Sensing Laboratory "mini" computer. The following steps can be taken: (1) the original NDPF tapes are reformatted to local standards, (2) the intensive study areas are selected from the bulk tape, (3) spectral training data are extracted from the intensive study sites, and (4) classification results are displayed on the color display. Further examples of the capabilities of this computer system will be demonstrated in the May, 1973 annual progress report.

4.3.1.2 Snow Surveys

A twofold research effort is proposed for this next reporting period with respect to snow surveys within the Feather River Watershed region. First, work will continue which is designed to document that areal estimates of snow cover can be made accurately, quickly and inexpensively using ERTS-1 data. The interpretation key and analysis techniques developed during this last reporting period with the aid of U-2 photography will be applied to ERTS-1 imagery taken during the 1972-73 melt season. Second, an effort will be made to integrate estimates of snow cover into working stream flow forecasting models. An example model is discussed below and was developed by Leaf and Haeffner.* This model is based on an estimate of areal snow cover and a precipitation index. Three types of information are needed in order to develop the forecast curves, which are used for predicting residual volume. These are (1) aerial (or satellite) images taken during the melt season, (2) precipitation data, and

*Leaf, D. F. and A. D. Haeffner. 1971. A Model for Updating Stream Flow Forecasts Based on Areal Snow Cover and a Precipitation Index. Presented at the Western Snow Conference, Billings, Montana, April 20-22, 1971.

(3) runoff data for the watershed in question.

Three steps need to be taken in developing runoff forecast curves. The first is to develop a snowpack depletion-runoff curve (see Figure 4.30) by plotting percentages of snowpack depletion and runoff. The relationship between snowpack depletion and runoff is fairly constant from year to year for any particular watershed, and thus, only a few years of data are needed to devise the curve.

By use of the "observed" runoff information contained in Figure 4.30, a graph showing snow cover depletion as a function of residual flow can be derived. The family of curves shown in Figure 4.31 accounts for both "high" and "low" snow years. "High" and "low" snow years are a function of the initial amount of snowpack according to Leaf and Haeffner.

Since the terms "high" and "low" are subjective and open for debate as to how much snow they represent, they must be quantified. This is done by using a precipitation index. The graph which results is shown in Figure 4.32. In order to calculate precipitation indices the average annual precipitation for the watershed in question must be known. Once this is known, index weight factors can be calculated. Index weight factors are simply the ratio between the precipitation for a specific time period and the total average annual precipitation.

By using the equation:

$$Ip = 100\ [W_m i_m + W_a i_a + W_m i_m + W_j i_j]$$

<u>where</u>

Ip is the weighted precipitation index

W_m is the weight factor for seasonal snow accumulation through March 30

SPANISH CREEK WATERSHED

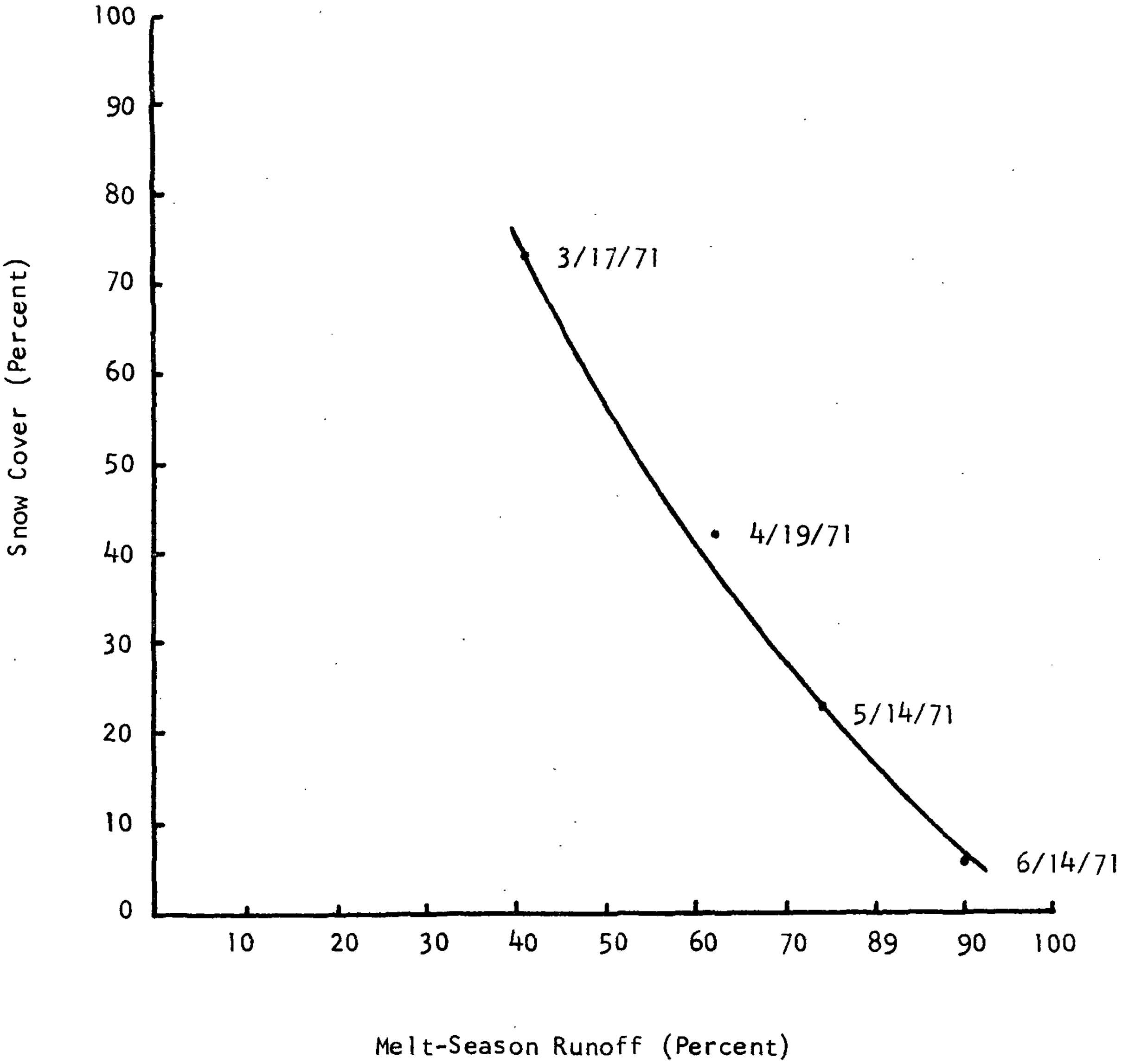


Figure 4.30. Snowcover depletion as a function of accumulated runoff, 1971. The curve is based on only one year's data. Accuracy should improve when it becomes possible to base such a curve on several years' data.

SPANISH CREEK WATERSHED

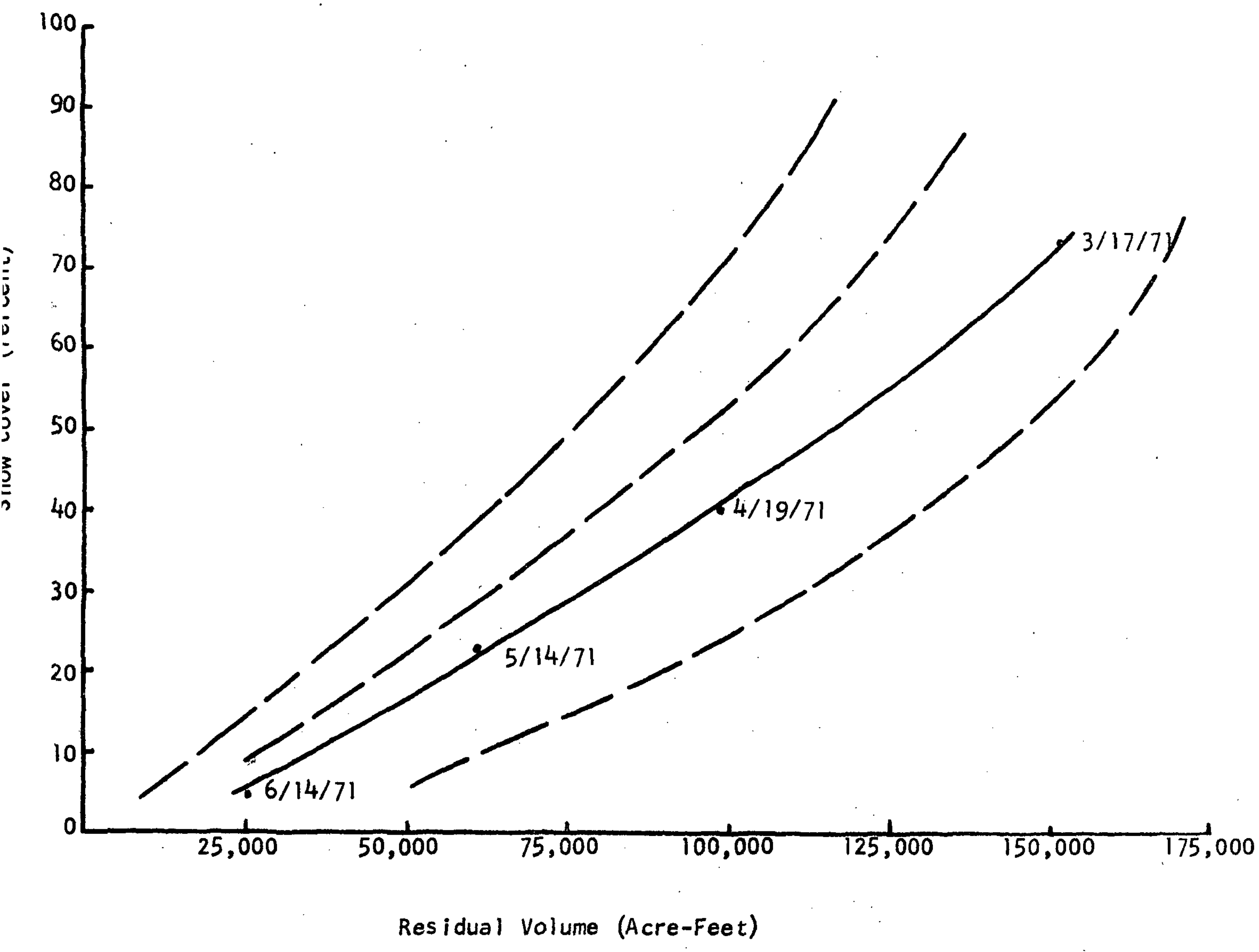


Figure 4.31. Snow cover depletion as a function of residual flow. The solid curve is based on valid 1971 data. The possible locations of additional curves, had data been available, are represented by the dashed lines.

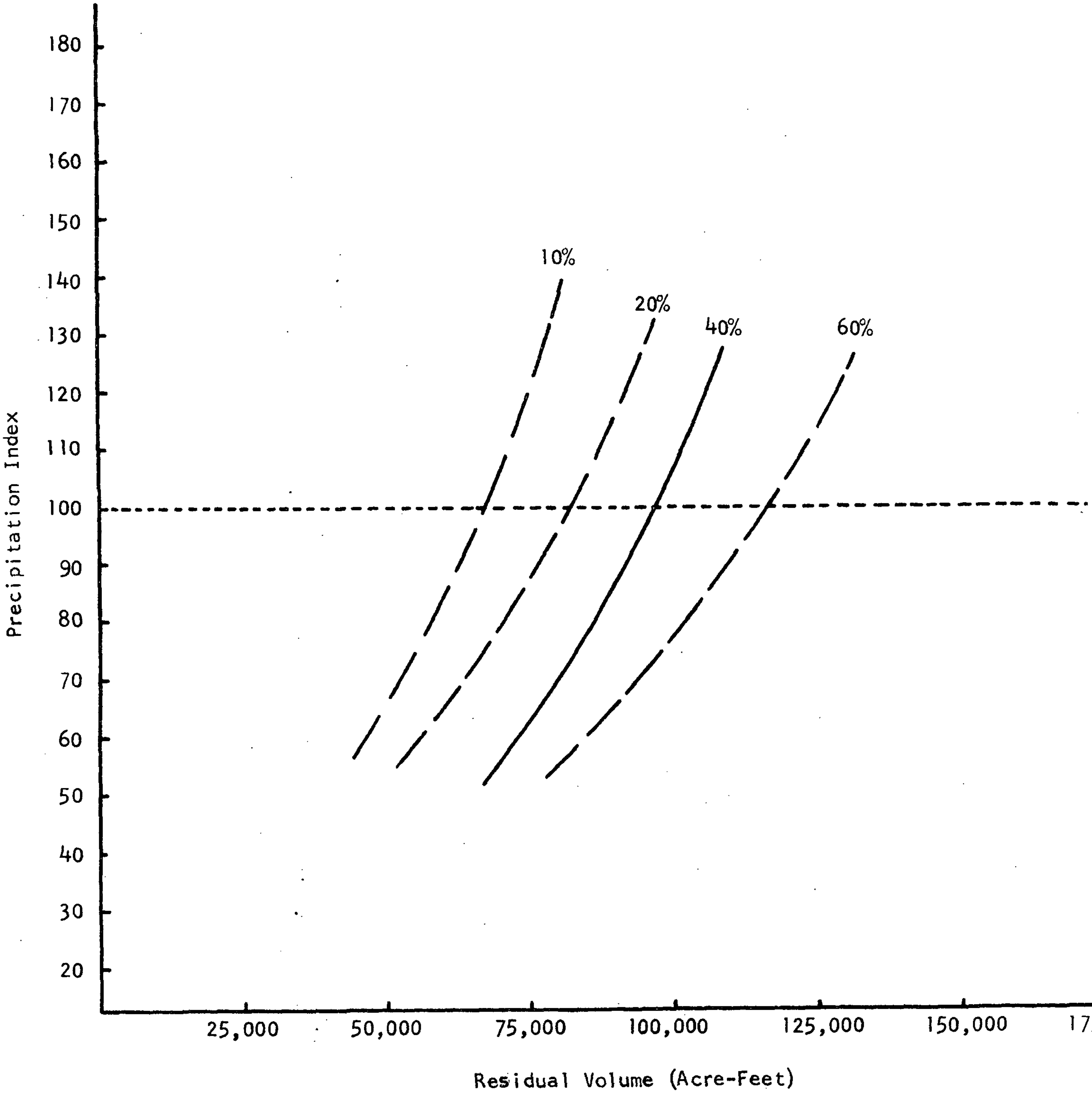


Figure 4.32. Snow cover precipitation index forecast curves. The solid line represents the actual location of the 40 percent curve, based on two observations of approximately 40 percent snow cover. The possible locations of additional snow cover percent curves are represented by the dashed lines.

i_m is the snow accumulation index through March 30 (ratio between observed value for the year in which forecast is being made and average value)

W_a is weight factor for April

W_m is weight factor for May

W_j is weight factor for June

i_a is the precipitation for April

i_m is the precipitation for May

i_j is the precipitation for June,

one is able to calculate the precipitation index and then, with knowledge of snow cover percent, determine the forecasted residual volume for any particular year. Table 4.12 illustrates how a precipitation index is calculated.

The precipitation index equation allows for adjustments as the melt season gets under way. For example, the precipitation index calculated on March 30 can be adjusted to reflect abnormal precipitation during the month of April by changing the weight factor (W_a). Leaf and Haeffner have shown that this adjustment process greatly increases the accuracy of the forecast.

The validity of the above forecasting model has been shown, using large-scale (1:6,000) photographs on small watersheds (< 2000 acres). It is anticipated that the forecasting model can give accurate forecasts on larger watershed and when using ERTS-1 imagery. Future research will involve using ERTS-1 imagery to acquire snow-cover percentages in order to construct the forecasting curves for the entire Feather River Watershed.

TABLE 4.12. EXAMPLE OF PROCEDURE FOLLOWED FOR DERIVING PRECIPITATION INDICES

Precipitation Summary 1967-72

Watershed	Peak (March 30)	April	May	June	Total
Spanish Creek	27.43	3.46	1.44	1.29	33.62

Index Weight Factors

Spanish Creek	.82	.11	.04	.03	1.00

Assume for year 1973, precipitation for March 30 = 20.00"

$$I_p = 100\left[\frac{20.0}{27.43}\ (.82) + 1.0(.11) + 1.0(.04) + 1.0(.03)\right]\ 77 = \text{precipitation index}$$

4.3.2 Analysis Within the Northern Coastal Zone

4.3.2.1 North Coastal Environment Planning and Classification Data

The Forestry Remote Sensing Laboratory (FRSL) will continue to orient its research towards determining what remote sensing system is operationally feasible for use by environmental planners at the regional level within the North Coast Test Site of California.

Increased interaction with planners is scheduled to include the planners of each county within the test area as well as other regional agencies (e.g., ABAG) and State agencies (e.g., California Coastal Zone Commission). It is hoped that through these interactions with the users, an adequate roster of planning needs and priorities can be more or less finalized. In addition, the quantification of what can be provided by the remote sensing tool in terms of accuracies and costs is expected to progress significantly.

4.3.2.2 Manual Analysis of ERTS-1 and Supporting Aircraft Data

Our determination of the amount of information of certain types which can be interpreted from ERTS-1 and high altitude photography is far from complete. Analysis plans call for additional interpreters to delineate and classify ERTS-1 imagery from the July 27 pass. This procedure will be repeated for other ERTS-1 passes where usable (good quality) imagery is available. Further emphasis will be given to determining what information can be extracted from the black-and-white MSS bands. It was apparent during this most recent phase of study that the mapping on individual bands was inferior to mapping on the color composite imagery but further analysis is required to determine what specialized mapping tasks can be accomplished through analysis of individual black-and-white MSS bands.

During the next reporting period, emphasis will be placed upon developing techniques for detecting features which have undergone change during the time interval between cloud free ERTS-1 passes. Attention will be devoted to the recording of all land parameters which can be monitored and which signify important changes in the environment. Documentation will also be made of those features which can be accurately detected, delineated, classified, and identified by virtue of their changing appearance during specific seasons.

All analysis procedures being applied in the southern intensive study area will be, or are being, applied in a northern study area, where resource types and land use patterns are significantly different. Moreover, a generalized land use map for the entire north coast of California will be prepared once cloud-free imagery (ERTS-1) of the entire test site area is available. The purpose of making this map is to determine if the level of information mapped over a large regional area is of value to regional planners. Finally, automated interpretation techniques will be applied to selected areas within the test site. Thus, the degree to which classification can be achieved of important land use categories by means of computer analysis will be evaluated.

4.3.2.3 Automatic Analysis of Aircraft Data at Boggs Mountain Data Bank Applications

The overlays that have been digitized for the Boggs Mountain area will be entered into "MAPIT" using various constraints of interest to the resource management agencies. The results will be representative resource maps of areas that meet management requirements for day-to-day management

programs. Furthermore, the overlays of timber typing by various discrimination methods will be compared in "MAPIT" to detect differences. The digitized ground data will be used to determine the accuracy of the various delineation methods.

At the present time "MAPIT" uses polygons as input and can generate polygons as output, but the logical operations between maps are done on a point-by-point basis after the polygons are converted to cells as specified by the user. Because of the costs associated with the generation and storage of these cells, software will be developed to work directly with the polygon data from the input.

Terrain Model

As indicated earlier in this Chapter, our approach to transformation from perspective to map projection is not satisfactory. High altitude photography will probably not be the final solution to the transformation problem. If there are substantial differences in elevation, the photo may not give area approximations accurately enough for all management purposes. One may also want to take advantage of a larger scale for resource classification purposes. Finally, for elevation, slope and aspect data, sources other than a single high altitude frame have to be employed. Therefore, an attempt to generate a model of terrain, that is, to fit the surface of terrain by analytical means (e.g., orthogonal polynomials), will be made. Source material for the modeling will be stereo pairs of photographs in any scale. Similar work has been done before, but no prototype model known to us has yet reached an operational level in terms of reasonable costs.

Feature Generation

As discussed earlier, spectral data alone are not always adequate for classifying wildland vegetation types accurately. Therefore, work is continuing on the development of textural features that can be used as input to the statistical classifier. The results of the correlation work described earlier, as well as current preliminary findings, are encouraging. Because topography is one of the dominant influences on the distribution of plant species and communities, work is being conducted (and is nearly completed) on a software package that will quantify elevation, slope, and aspect for use as separate features in the statistical classifier. This added information will significantly increase the classification results over pure spectral classification. In biological research it will allow the study of the correlation between plant relationships and the physiographic features. Other environmental parameters such as rainfall, temperature, distance from the coast, and distance from ridge tops will be investigated as primitive features for the classifier.

Evaluation and Improvement of Automatic Timber Typing

The CALSCAN package produces what, by inspection, appears to be reasonably accurate timber typing. A natural next phase of study is to evaluate its performance in quantitative terms. This can be done by employing techniques recently developed at the FRSL.

Hardware

It has been shown that through the use of a "mini computer" to handle preprocessing and post-processing tasks in an interactive mode, a significant increase in cost effectiveness can be realized. We propose to upgrade

the local processing capabilities to the extent that the majority of the processing will be done at the local level in order to take full advantage of the economies of the "mini computer".

4.3.2.4 Analysis of Wildland Burned Areas on ERTS-1 Data

The Forestry Remote Sensing Laboratory (FRSL) will continue its sequential ERTS-1 and U-2 monitoring of the Pocket Gulch and Fiske Creek fire areas, with emphasis on detecting and measuring revegetation progress and soil erosion as it proceeds throughout the season, following a burn. This analysis will continue to be supported with low altitude photography and on-the-ground data collection by both the FRSL and the California Division of Forestry (CDF), notably Mr. Fred Batchelor of the Spanish Flat Station. Other fires in Northern California for which pre-burn as well as post-burn imagery is available will also be analyzed to further improve current techniques for damage assessment and revegetation prescription.

Image evaluation techniques for post-fire mapping will themselves continue to be evaluated and upgraded. This will include testing various methods of image enhancement (Diazo composites, photographic technique-NASA method, etc.) to reduce manual interpretation problems. Also, improvements can be expected in some aspects of the CALSCAN automatic image interpretation process through better training cell delineation. The utility of automatic data banks to post-burn analysis, as represented by MAPIT, will also be assessed.

Throughout the program of investigation into applications of remote sensing to post-fire wildland mapping, interaction and cooperation will continue to be carried out between the FRSL and relevant user groups, such as the CDR, BLM and USFS.

Chapter 5

RIVER MEANDER STUDIES

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5.1 INTRODUCTION

Under the NASA supported "Integrated Study" we are conducting a basic investigation dealing with the correlation between river meander patterns and discharge rates. We are attempting to extract data on the total discharge of a river, both past and present, from aerial photography and spectral analyses of river meander patterns. The purpose of this research is to develop a relatively simple and inexpensive technique to assess the water resources of large, relatively undeveloped geographical areas in order that comprehensive water development plans may be prepared with less expenditure of money and time for the collection of data on the earth's surface. Since most river drainage basins in the United States have already undergone substantial development, and since river discharge and rainfall data are reasonably complete in this region, we expect this technique to be of value largely in underdeveloped and poorly surveyed areas of the world. However, data available on rivers in the United States will serve to validate the technique. Indirect information on the average rainfall over large drainage basins could also be obtained by relating these flow estimates to the geographical areas involved.

Finally, this study will benefit hydrologic development in that it should result in new criteria by which the stability of a meander pattern at arbitrary discharge may be determined. Such an examination would then

be used as part of the evidence in the decision as to whether existing river control systems -- levees, check dams, and diversion areas -- are adequate at some assumed flood stage, or whether additional control facilities must be built. It is already clear that at some flood stage, rivers produce rapid, often disastrous, alterations in their meander patterns, and it is an objective of our study to see if such alterations can be anticipated.

As a basis for this study we have developed a fully automated system for obtaining and analyzing the spectrum of meander wavelengths from sequential low altitude aerial photographs of a stream channel. This system involves three elements: digitization of the stream banks on each photographic frame; collation and matching of successive frames into a single data record for each stream; and a fast Fourier transform analysis of the data to obtain the meander wavelength spectra. The digitization of the river meander patterns is done by photoelectric optical scanning using the Programmable Film Reader/Recorder developed by Information International Inc., Los Angeles.

The validation of this technique on a statistical basis is the objective of the proposed work. The statistical reliability of any correlation between the meander spectrum and the discharge frequency distribution depends upon the study of a large number of rivers whose discharges cover as great a range as possible. However, using low altitude aerial photography, the study of many rivers is a costly and time consuming procedure. These disadvantages result primarily from the fact that ten to one hundred low altitude overlapping photographs are usually required to cover a significant reach of a single river. Thus a large fraction of the costs arise

from the acquisition, collation and matching of the many individually digitized river segments.

The large area covered in a single space photograph or very high altitude aerial photograph, however, will enable us to greatly reduce these costs since in most cases only one or two images will cover an adequate reach of a river.

5.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

We have nearly completed the production of the stream discharge frequency distributions and the meander power spectra of a number of rivers, and we soon will be in a position to undertake the last step of our analysis -- the study of the relationship between the meander power spectra and the corresponding discharge spectra.

The meander power spectrum for a particular reach of river is constructed from a series of values of local river direction θ as a function of distance along the course of the river. The power spectral density (deg^2/1000 ft.) for the direction θ as a function of the meander wavelength (1000 ft.) is computed using standard techniques for determining the autocorrelation function, smoothing and taking the Fourier transform (e.g., see J. S. Bendat and A. G. Piersol, Measurement and Analysis of Random Data, Wiley, 1966).

A typical power spectrum which we have developed during the present reporting period is shown in Figure 5.1 for a reach of the Feather River. The actual meander pattern for the reach, digitized from aerial photography, is also shown. The length of the reach, measured along the course of the river (120,000 ft.), has been chosen so that it is more than an order of magnitude greater than the wavelength ($\sim$ 6000 ft.) at which the

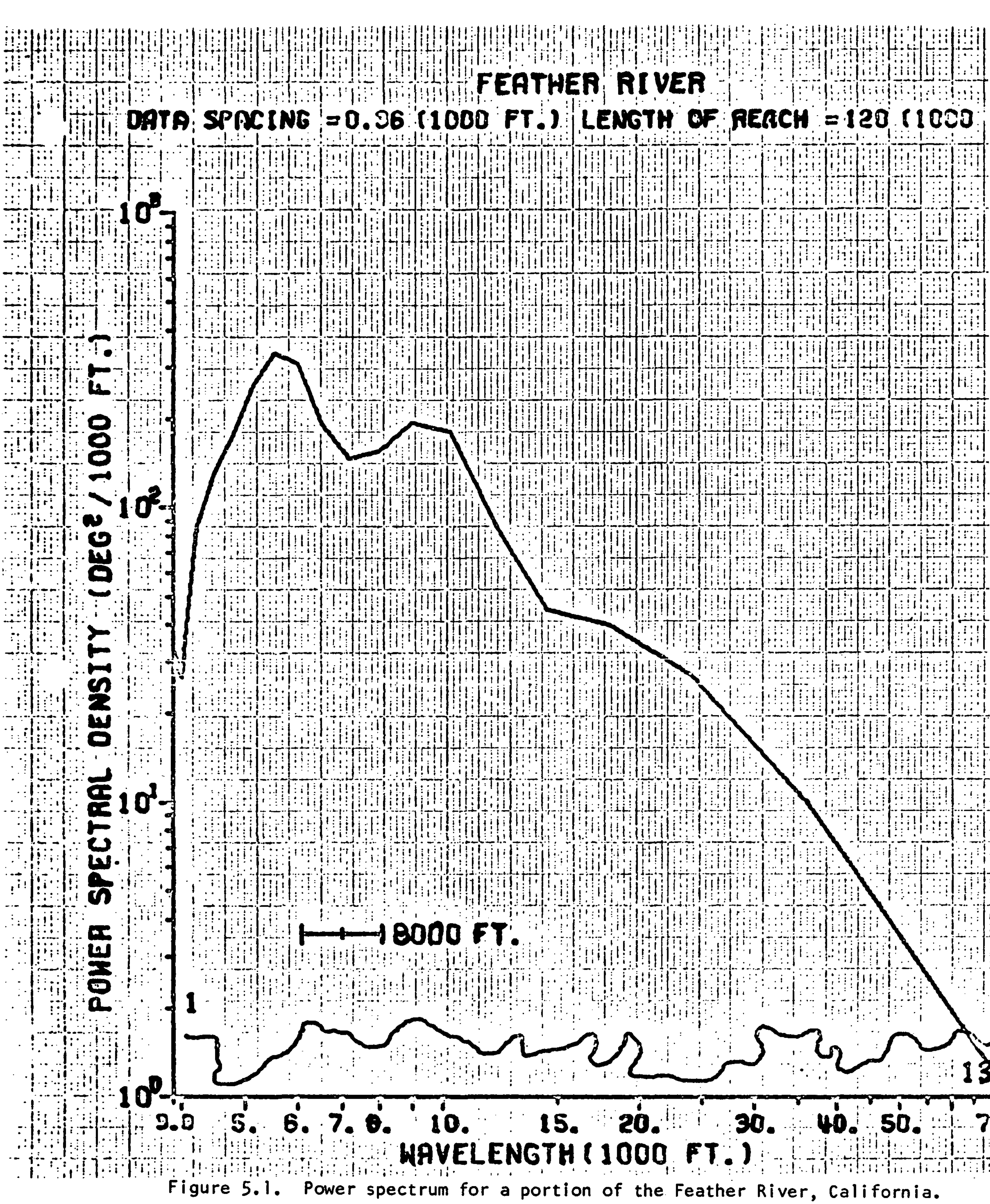

Figure 5.1. Power spectrum for a portion of the Feather River, California.

peak in the power spectral density occurs. Similarly the data spacing used in the spectral analysis, i.e., the distance between successive values of θ (360 ft.), has been chosen so that it is more than an order of magnitude less than the peak power wavelength. In the case of the Feather River, the basic data set, digitized from the aerial photography, had 1337 θ values spaced every 90 ft. along the reach. Four-point averages were used to obtain the 334 θ values used in the spectral analysis. The number of degrees of freedom (twice the number of data values used in the spectral analysis divided by the number of power spectral estimates) is a measure of the degree of confidence in the determination of the spectrum. For power spectral density determination shown in Figure 5.1, there are 6.7 degrees of freedom which gives us $\sim$ 80 percent confidence that the spectral values lie within 2.8 and 0.5 times the computed estimate (see e.g., R. B. Blackman and J. W. Tukey, The Measurement of Power Spectra, Dover, 1958). Thus the peak density of about 300 deg^2/1000 ft. at a wavelength of about 6000 ft. is clearly well above the small scale noise level of about 30 deg^2/1000 ft. which extends from about 4000 ft. to smaller wavelengths not shown in this figure.

The fine structure in the spectrum, i.e., the suggestion of a secondary peak at about 9000 ft. in Figure 5.1, is not resolved within these confidence limits. However, additional spectral information can be obtained from analysis of shorter segments of this reach of the Feather River. Separate power spectra for the upstream and downstream halves of this reach, Figures 5.2a and 5.2b, respectively, suggest a variation in the peak wavelength along the reach with relatively more power at the 9000 ft. wavelength on the upstream half of the reach. This variation can be more

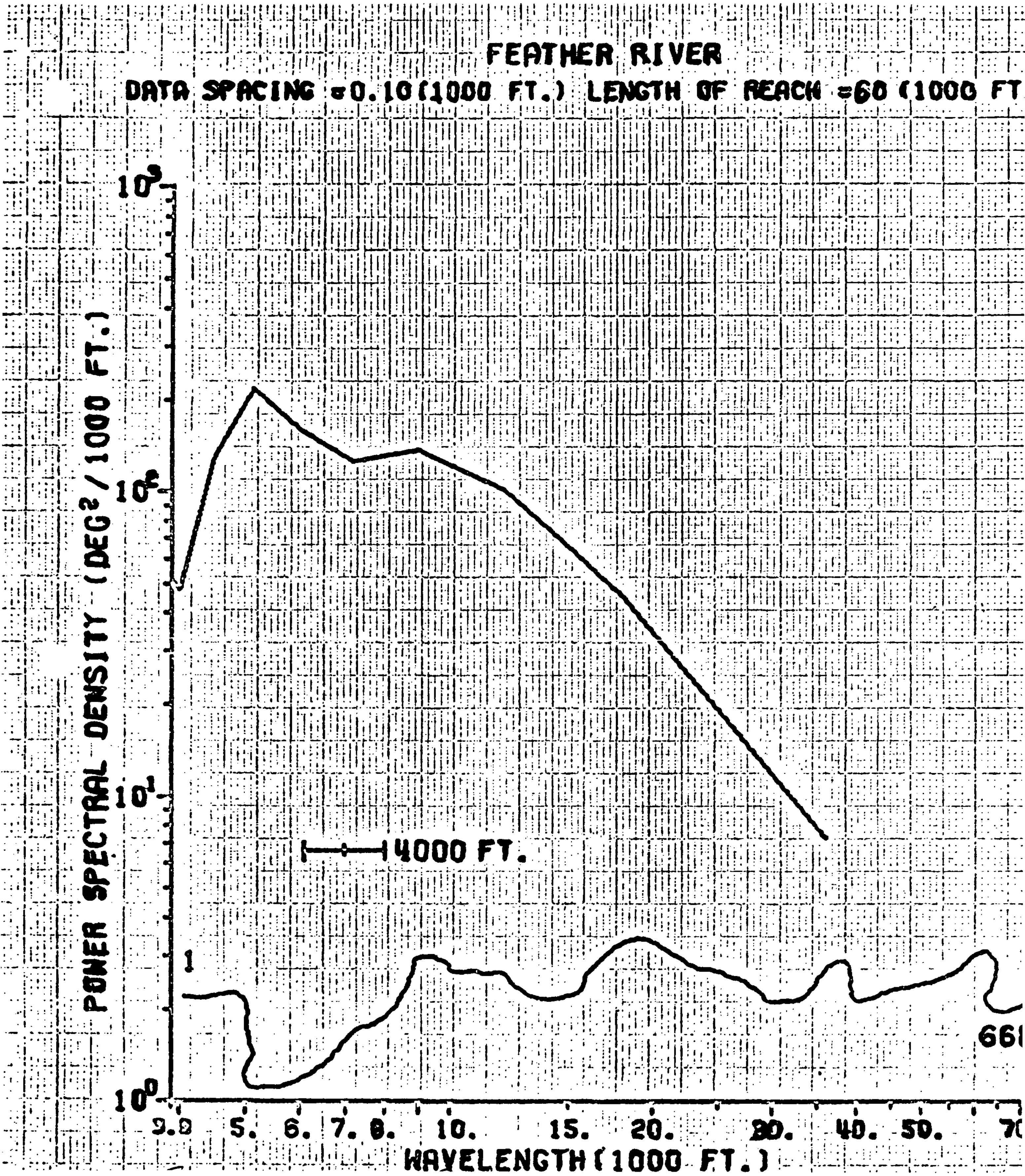

Figure 5.2a. Power spectrum for upstream half of the reach shown in Figure 5.1.

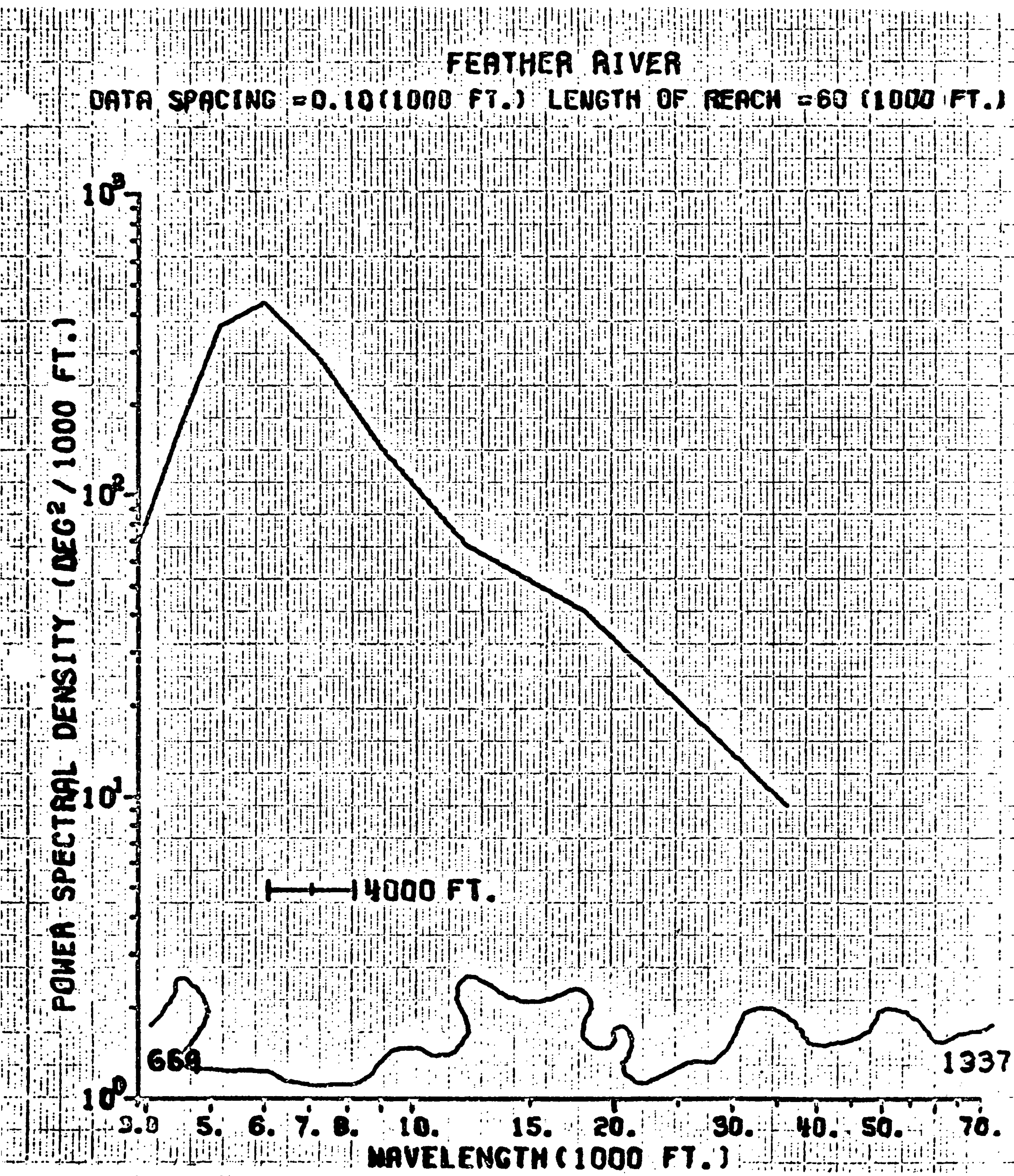

Figure 5.2b. Power spectrum for downstream half of the reach shown in Figure 5.1.

clearly seen by further division of the reach into thirds, Figures 5.3a, b and c. The spectra for these segments show that in the upstream third (Figure 5.3a) the power in fact peaks at 9000 ft.; in the middle third (Figure 5.3b) there is a broad peak between 6000 ft. and 9000 ft.; and in the downstream third (Figure 5.3c) there is a strong single peak only at 6000 ft.

Similar fine structure in a river meander power spectrum, associated with variations in the peak power wavelength along the reach, can be seen from the spectra of the Manistique River shown in Figures 5.4 and 5.5. The power spectral density of the 42,000 ft. reach of the Manistique River (Figure 5.4) has peaks at wavelengths of about 1200, 2000 and 3500 ft. For the 9.6 degrees of freedom with which the spectrum was obtained, the 80 percent confidence interval lies between 0.6 and 2.0 times the value of each spectral estimate. Thus the individual peaks shown in Figure 5.4 cannot be unambiguously resolved with 9.6 degrees of freedom, but their existence can again be established by spectral analysis of shorter portions of the reach. The spectrum of the upstream third (Figure 5.5) shows a strong single peak at ∿ 1200 ft., while the spectrum of the downstream two-thirds shows a broad peak at ∿ 2000 ft.

Not all fine structure in river meander power spectra is associated with variations over the reach as can be seen from the power spectra of the Manistee River (Figures 5.6a, b, c, d). The power spectra of four different reaches of this river all show two broad but well-defined peaks at ∿ 2000 ft. and ∿ 10,000 ft. The meander patterns shown on the figures clearly show these two distinct wavelength scales on all portions of the river.

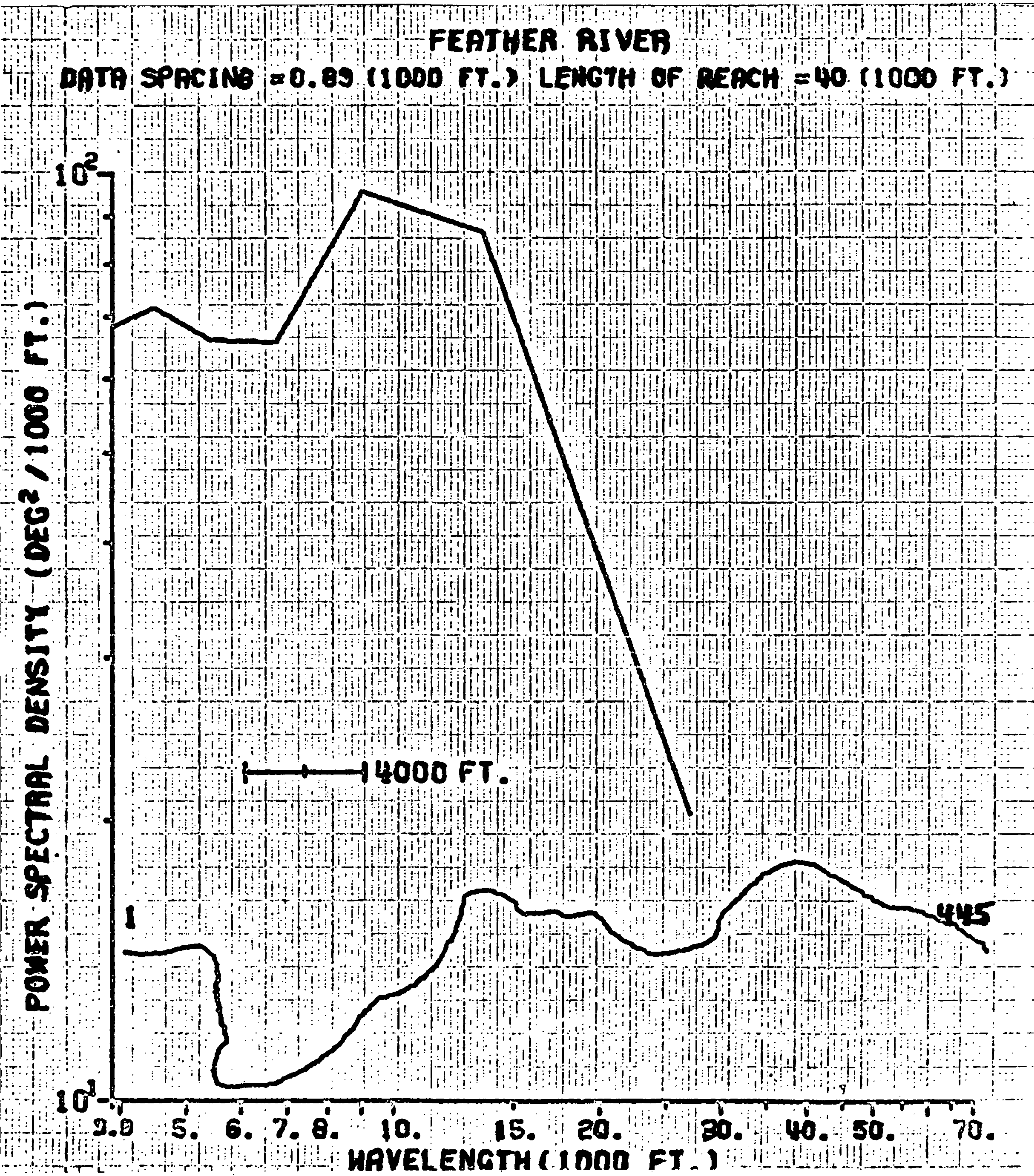

Figure 5.3a. Power spectrum for the upstream third of the reach shown in Figure 5.1.

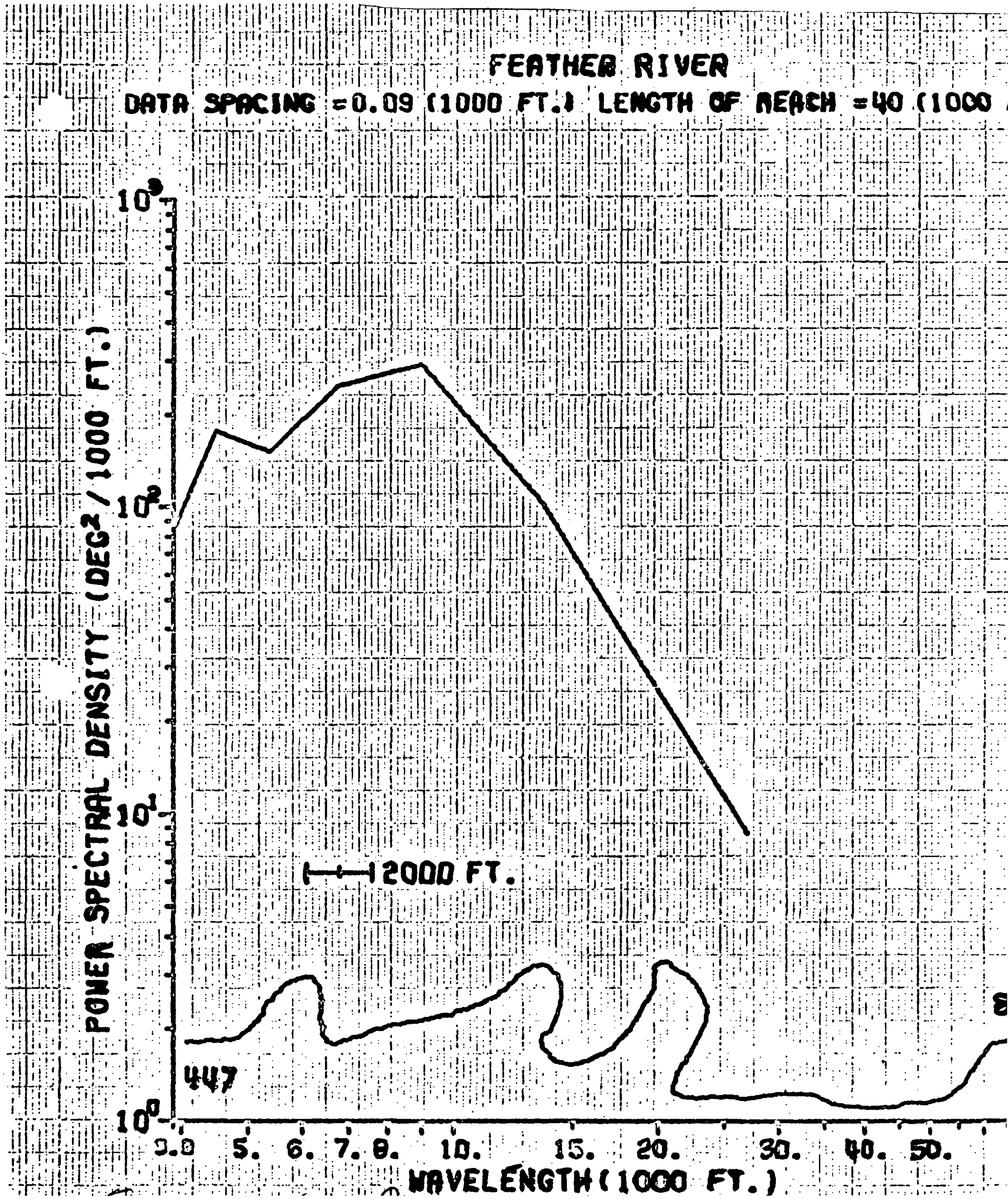

Figure 5.3b. Power spectrum for the middle third of the reach shown in Figure 5.1.

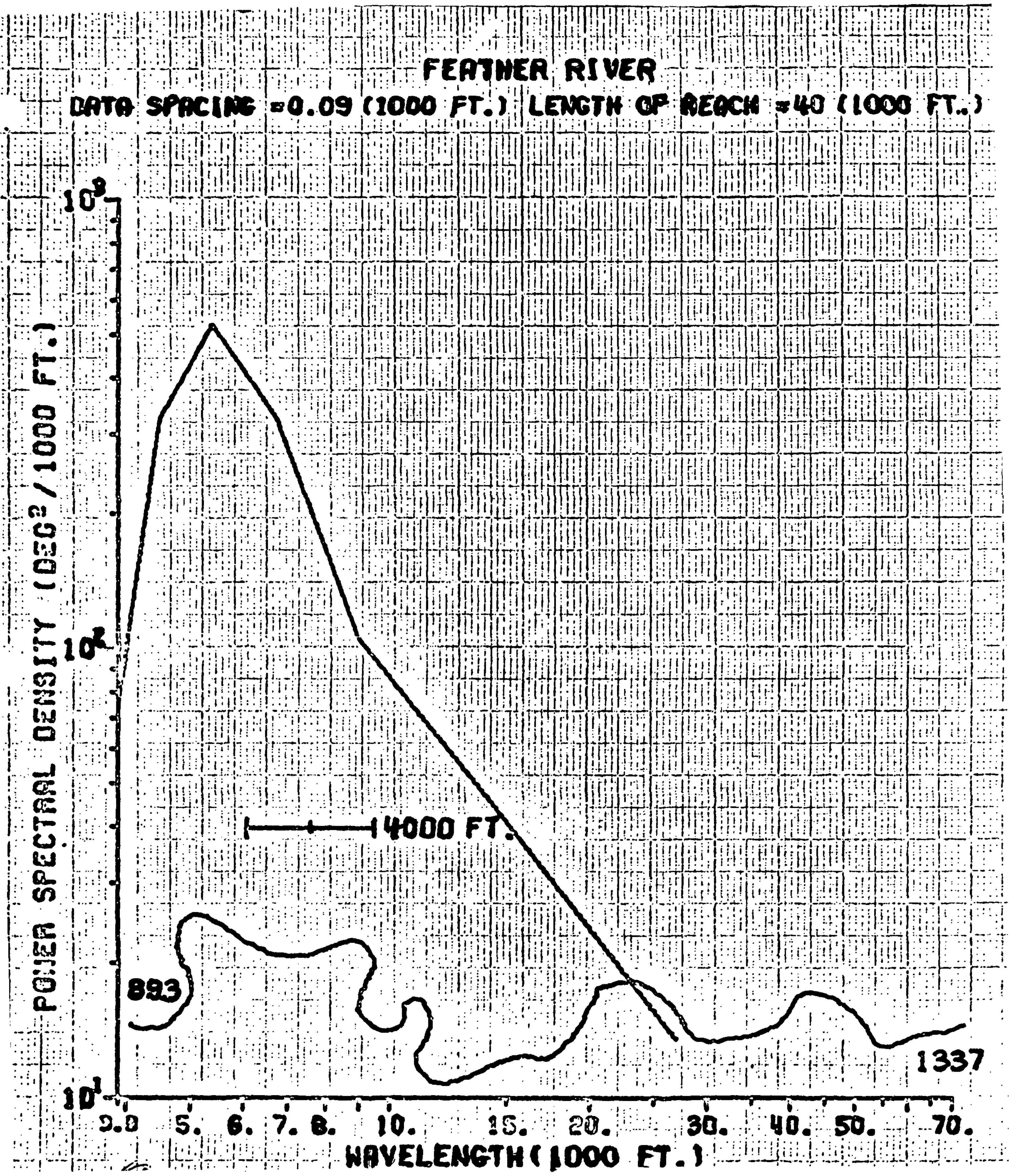

Figure 5.3c. Power spectrum for the downstream third of the reach shown in Figure 5.1.

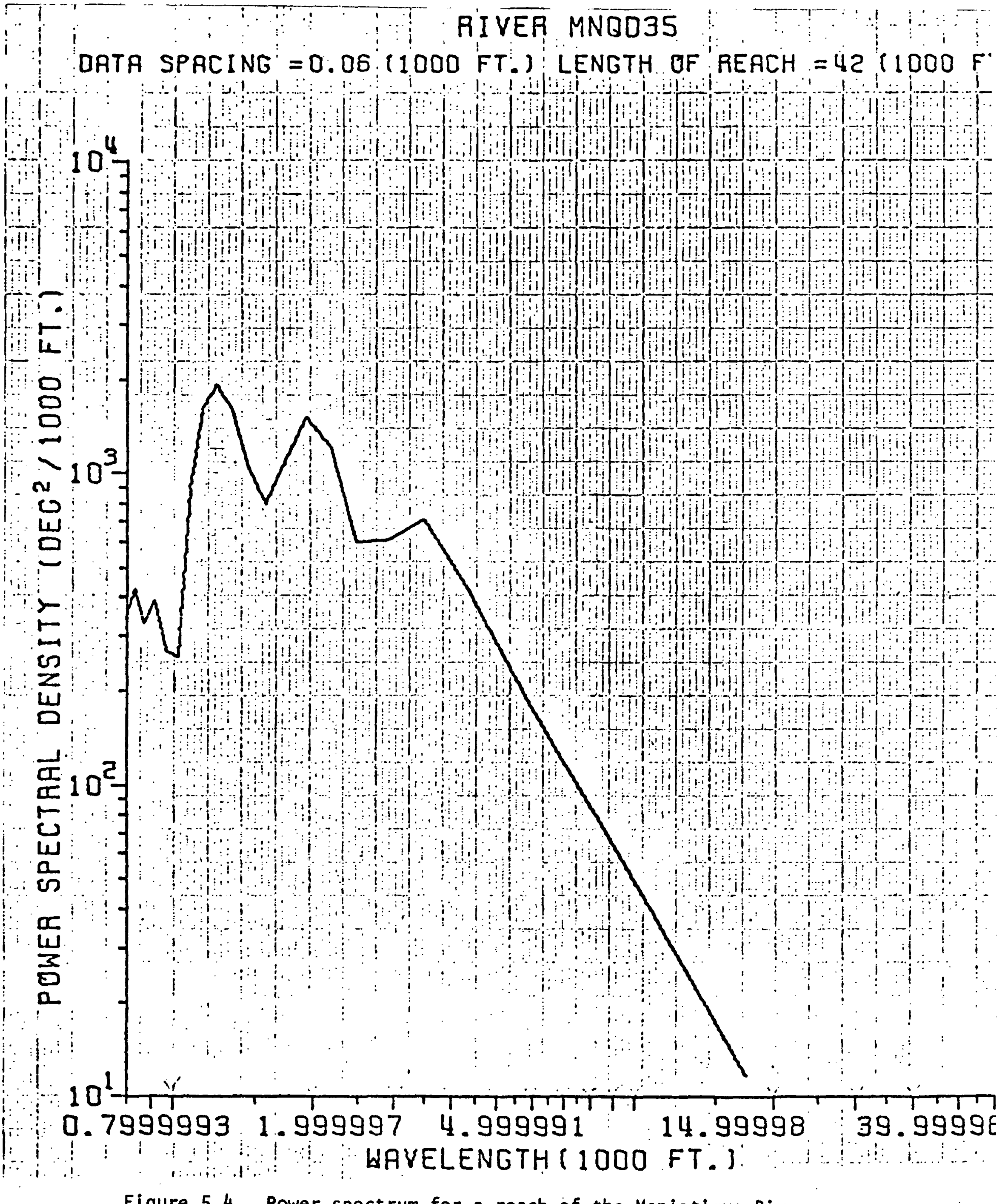

Figure 5.4. Power spectrum for a reach of the Manistique River.

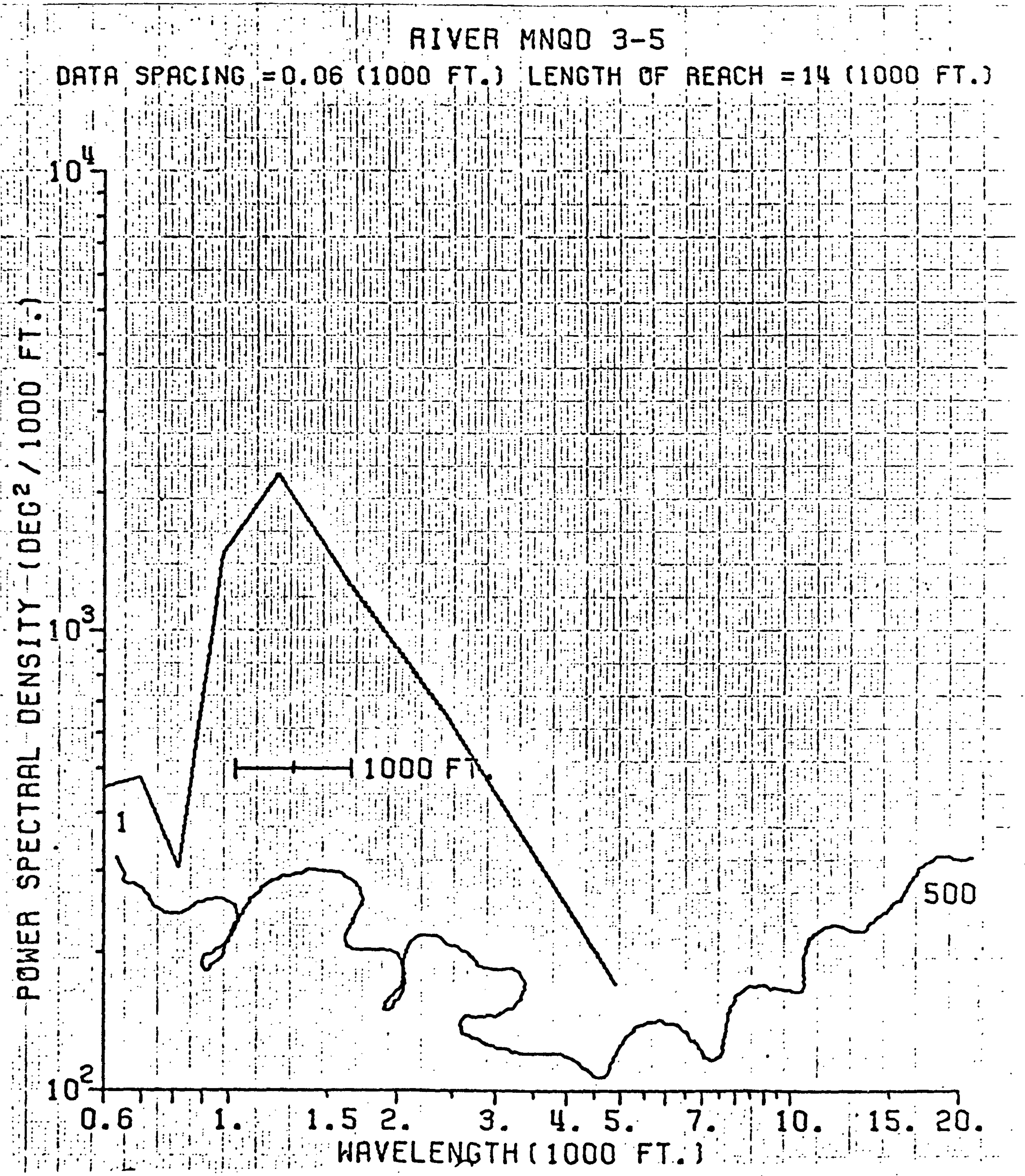

Figure 5.5. Power spectrum for upstream third of the reach shown in Figure 5.4.

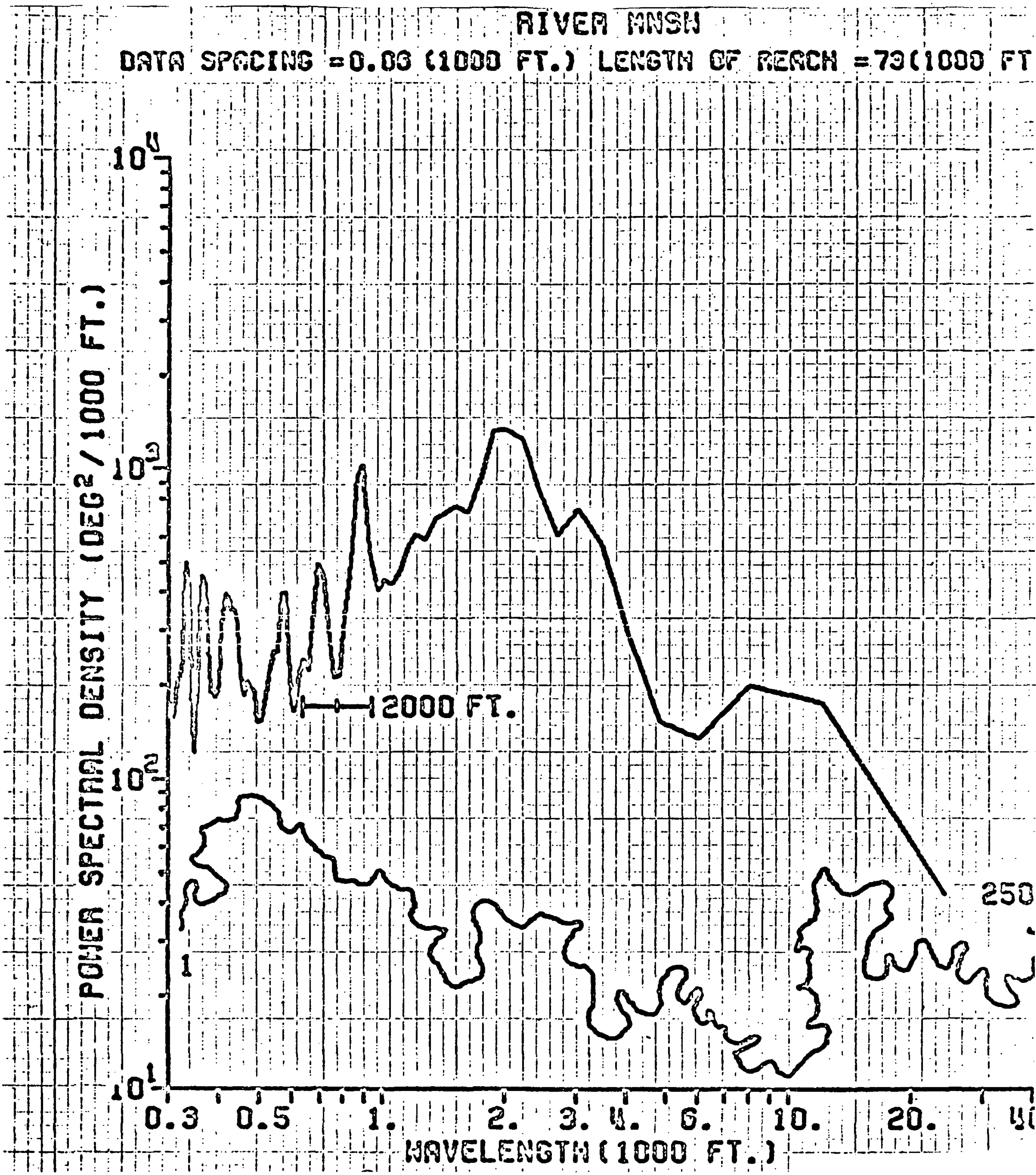

Figure 5.6a. Power spectrum for the first of 4 reaches of the Manistee River.

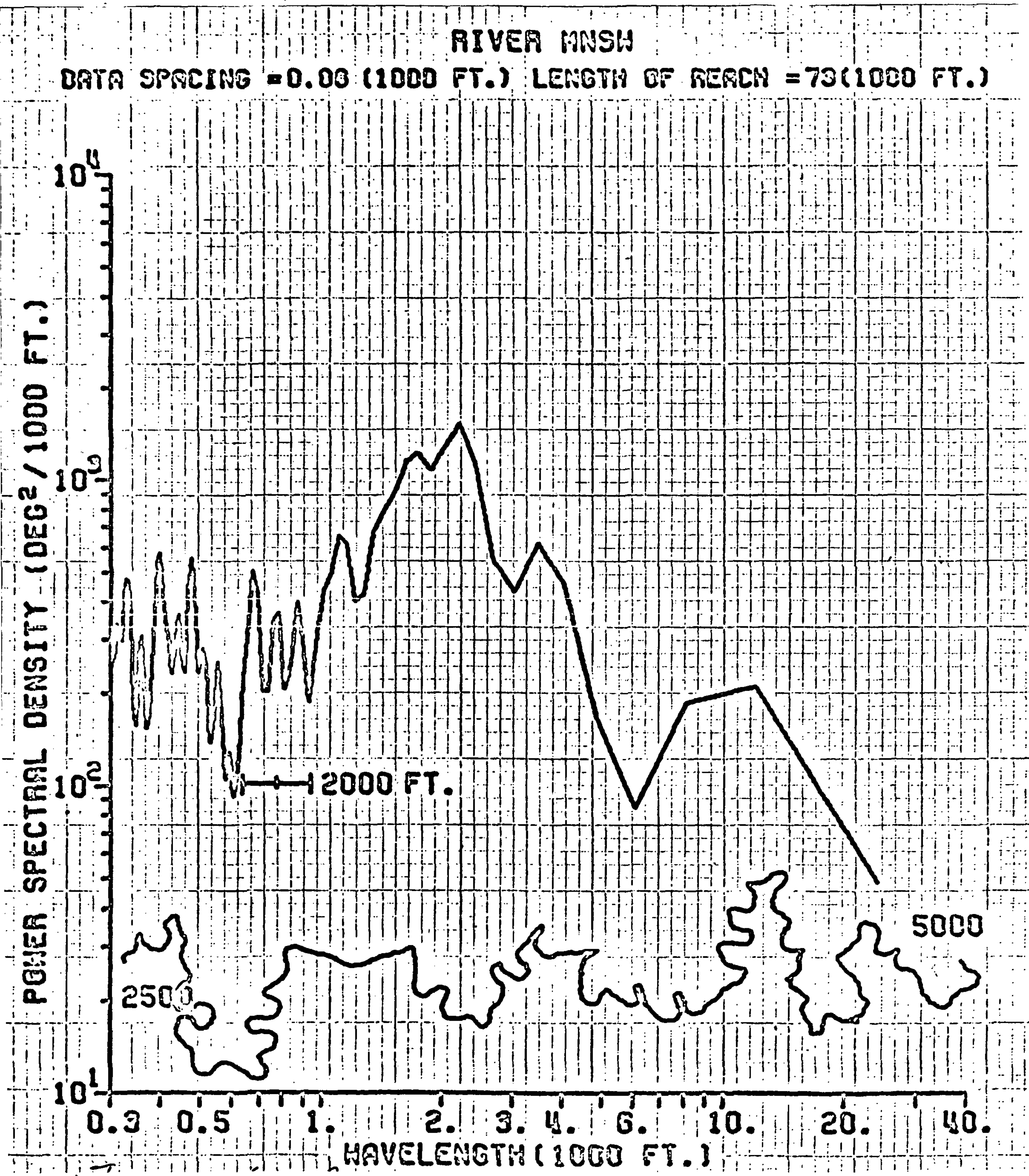

Figure 5.6b. Power spectrum for the second of 4 reaches of the Manistee River.

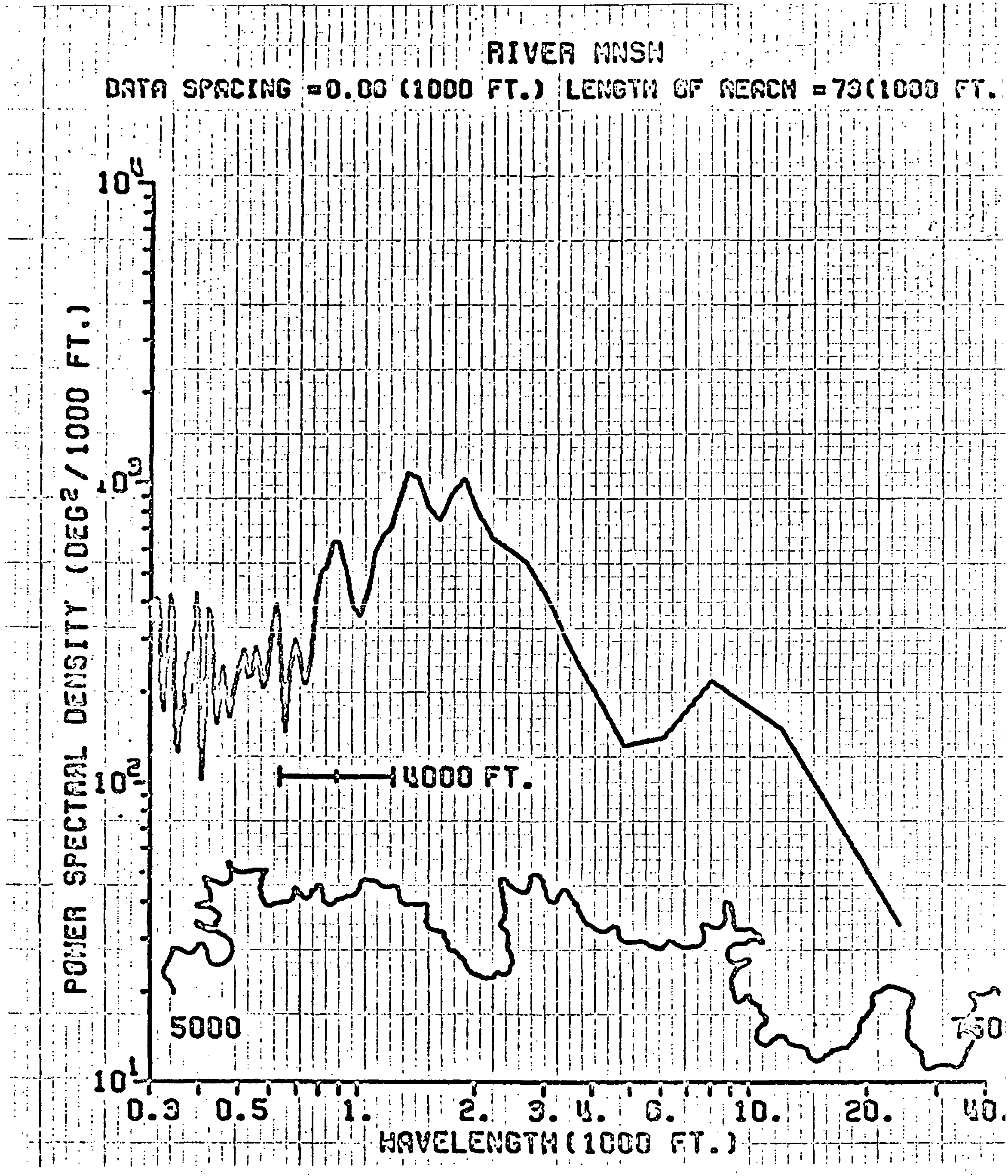

Figure 5.6c. Power spectrum for the third of 4 reaches of the Manistee River.

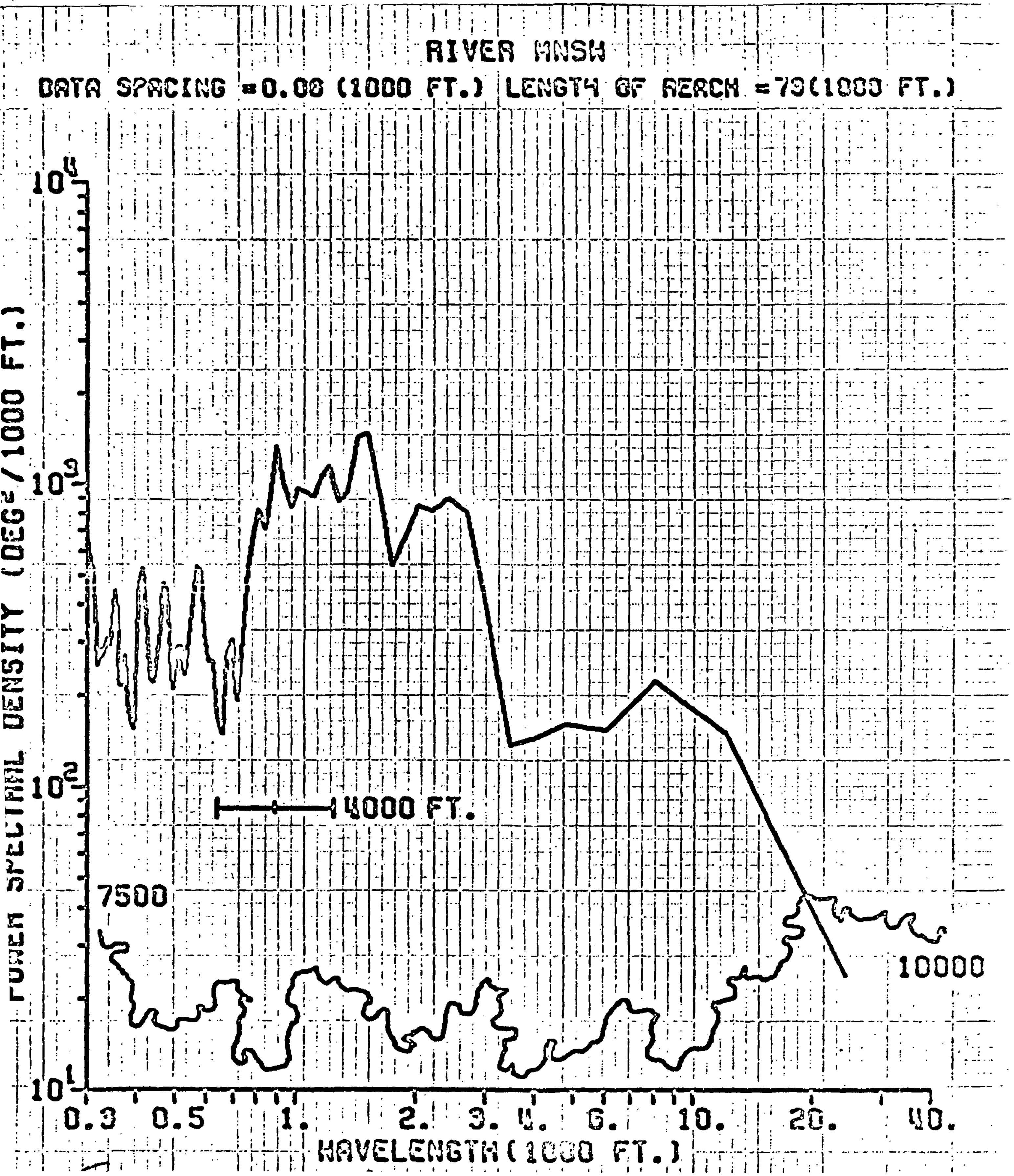

Figure 5.6d. Power spectrum for the fourth of 4 reaches of the Manistee River.

Preliminary comparisons are presently being made of these power spectra with their corresponding discharge-frequency distributions (see the May 1972 Annual Progress Report for examples of such distributions). There is a suggestion of a correlation between the peak power wavelength and the most frequent discharge. Studies are now being undertaken to attempt to understand the nature of the correlation, using the spectra which we have already produced together with the spectra we are presently producing from the ERTS-1 imagery. This gives us an extensive data base, having a wide range of discharges and wavelengths, on which to base our final studies. These studies will involve evaluation of models which attempt to correlate the entire discharge frequency spectrum of a river with its entire meander power spectrum.

5.3 FUTURE PROPOSED WORK

As previously indicated we soon will be in a position to undertake the last step of our analysis, viz. a study of the relationship between the meander power spectra and the corresponding discharge spectra.

The meander power spectrum for a particular reach of river is constructed from a series of values of local river direction as a function of distance along the course of the river. It is computed as described earlier in this paper and leads to results of the type presented in Figures 5.1 through 5.6. Until recently we had been limited almost entirely to the use of conventional aerial photography in making such determinations and hence were limited in the length of reach of a river (and correspondingly in the size of river) which could be feasibly studied on the limited number of photos to which the technique adapts itself.

Discharge rates associated with the relatively small rivers that we have been able to study to date span scarcely one "decade" (ranging from about 100 to 1000 cubic feet per minute). Now that space photography with its very large synoptic capability is becoming available to use we anticipate being able to use the same techniques, again on only a few photographs, but for very large rivers such as the Mississippi and the Amazon having discharge rates in the order of several hundred thousand cubic feet per second. Consequently we will be able to apply our correlation analysis over a far more meaningful range of stream discharge rates and associated meander power spectra as we bring this work to a definitive conclusion.

Chapter 6

ASSESSMENT OF RESOURCES IN THE CENTRAL REGIONAL TEST SITE

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Contributors: Leslie W. Senger, Randolph R. Thaman, Steven Kraus, Stephen Oliva, Lyndon Wester, Kris Bjorklund, Dal Cottrell
Geography Remote Sensing Unit, Santa Barbara Campus

The Geography Remote Sensing Unit (GRSU) on the Santa Barbara campus is responsible for the Central Regional Test Site (see Figure 6.1). Although some of the studies being conducted and reported on here are area specific, they are designed to have broad regional implications. The research focus of GRSU is an investigation of remote sensing applications that contribute to an understanding of processes and phenomena of resource significance in this test area.

Information is currently being extracted from Mission 164 and ERTS-simulation high flight imagery relative to: (1) population estimation; (2) the amount and distribution of cultivated land in Kern County, California; (3) construction of a vegetation map of the West Side of the San Joaquin Valley; (4) development of a standardized multi-functional data base for the Central Coastal Zone of the State of California; and (5) an analysis of land use change in the Goleta Valley, Santa Barbara County, California.

The Central Regional Test Site is primarily composed of ten central California counties, with integrated study overlap areas along the coastal zone to the north and south (Figure 6.1). The study site basically extends from Monterey to Ventura Counties, north and south respectively,

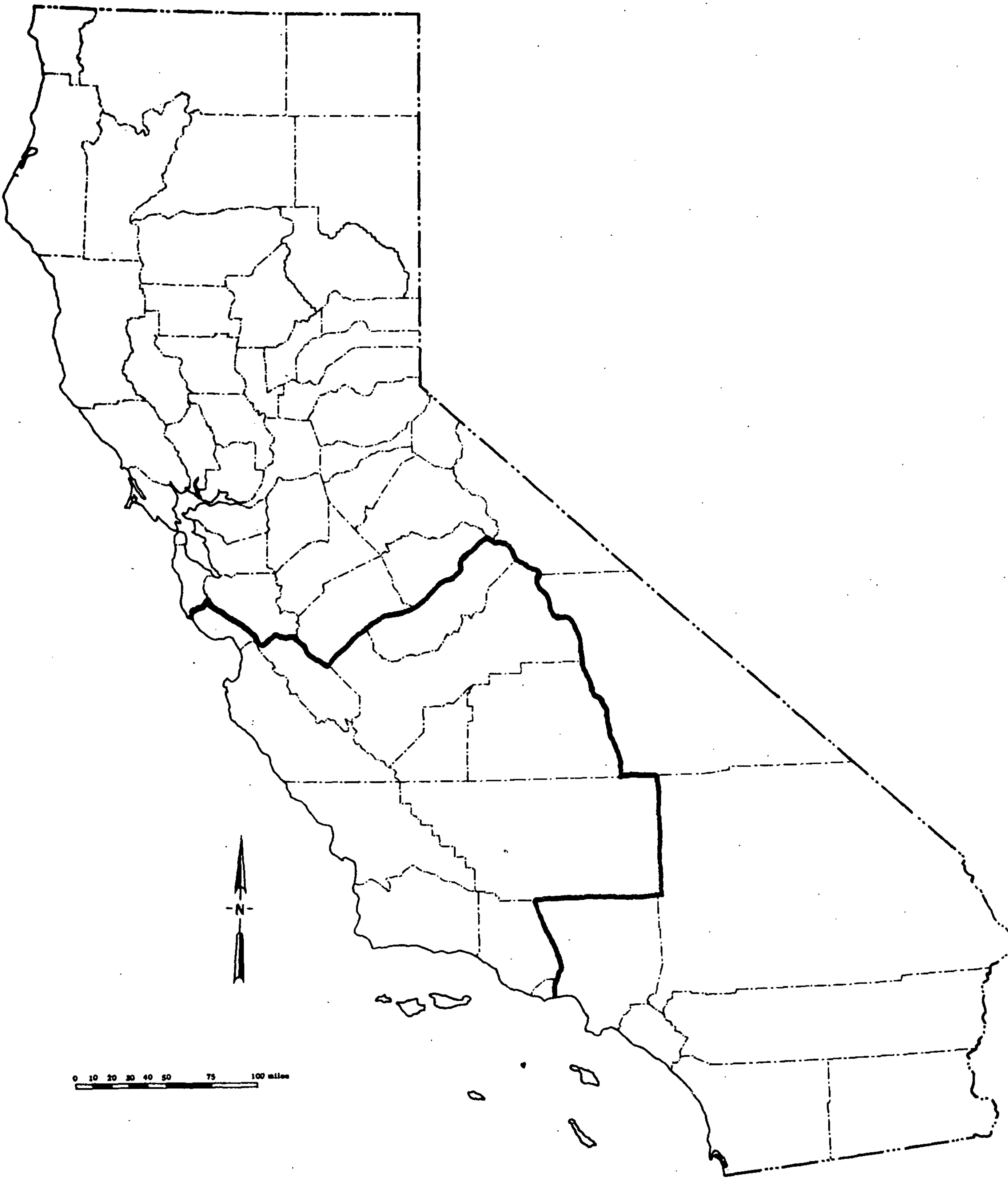


Figure 6.1. Central Regional Test Site, California

and from the coast on the west to the crest of the Sierra Nevada Mountains in the east. Areas of integrated intercampus overlap extend to San Francisco in the northern coastal zone and Santa Monica in the south. It is within this broad regional context that the studies reported on here have been carried out. The following sections of this report are provided to indicate the specific nature of these studies and progress which has been made in conducting them.

6.1 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

6.1.1 <u>Population Estimation</u>

Every ten years, the U.S. Bureau of Census carries out a massive, expensive, and time-consuming analysis of the population of the United States. While the results of the census are statistically accurate and useful in the period immediately following the collection of the data, they can obviously become outdated and inaccurate owing to the lag time before the census data are published, the ten year interval between censuses, and the rapid growth characteristics of many urban areas. Those aware of this tendency towards statistical obsolescence in the real world of dynamic population growth have voiced the need for an interim method of updating census information. Hence, the general purpose of this study is to develop an accurate and inexpensive method to estimate inter-censal population change in urban areas.

Before the present study was initiated, a thorough search of the professional literature on population estimation was undertaken. The results of this search were disappointing owing to the small quantity of material discovered and the general lack of accuracy exhibited by the

existing methods. Nevertheless, several papers provided valuable background for the present study and serve as standards by which a developed methodology can be compared.

The remainder of this section concerns a general description of the present study including discussion of a proposed methodology for population estimation and the results obtained from applying this method to two urban areas. Also included is a preliminary evaluation of this method based on the results obtained thus far from its application.

6.1.1.1 <u>Methodology</u>

It was decided that the primary data source for this study of population estimation would be aerial photographic imagery. This decision was based upon three factors: (1) the relatively low cost of aerial photographic imagery compared to conventional census-taking methods; (2) the ease of obtaining such imagery from governmental or private sources; and, (3) the advantages associated with the synoptic view inherent in aerial photographic imagery. It was also decided that a method for population estimation should be equally applicable to urban areas of all sizes and of differing cultural/environmental settings. Therefore, twenty cities in central and southern California were chosen for which NASA high flight imagery was available, and which represented a wide range of sizes and cultural/environmental situations. The twenty cities are listed in Table 6.1 according to six size categories.

The preliminary methodology, which was devised for estimating the population size of the twenty cities, consists of a simple function relating the measured area of three dominant residential land use types

and the characteristic spatial population densities associated with each. The measured area of residential land use types can be obtained from aerial photography at any time in the inter-censal period. Characteristic population densities for each residential land use type can be extracted from the most recent U.S. Census. The areal data from aerial photography are then combined with the characteristic spatial population densities to yield an estimated population for the area under study.

For the present study, the following aerial photographic imagery was used.

1. NASA High Flight 70mm B & W panchromatic (red and green bands) photography, flown April 4, 1971.

2. NASA high flight 9" x 9", Color Infrared photography, approximate scales 1:120,000 and 1:60,000, flown April 4, 1971.

This imagery was considered optimal because it was flown less than 1 year from the time that census data were collected for each study city.

Each of the twenty cities will be mapped from optically enlarged 70mm B & W imagery according to the following land use system:

R_1 - Single family residence,

Rm - Multi-family residence,

Tp - Trailer park residence,

C - All commercial or industrial uses.

The 9 x 9 color infrared imagery will be used with a 10X magnifier, in conjunction with the 70mm imagery, as an aid in the interpretation of land uses. Ground truth will be used to check the accuracy of interpretation in twelve selected cities. The area devoted to each mapped land use will

TABLE 6.1. POPULATION ESTIMATION STUDY CITIES

SIZE CATEGORY 1: Over 125,000

City	County	Pop.*
Fresno	Fresno	165,990
Santa Barbara Area: Santa Barbara (70,215) Goleta (50,000 est.) Montecito (8,000 est.)	Santa Barbara	128,215+ (est.)

SIZE CATEGORY 2: 75,000-125,000

City	County	Pop.*
Oxnard Area: Oxnard (71,225) Port Hueneme (14,295)	Ventura	85,520+
Concord	Contra Costa	85,423
Monterey Area: Seaside (35,935) Monterey (26,302) Pacific Grove (13,505) Carmel-by-Sea (4,525) Del Rey Oaks (1,823)	Monterey	82,090±

SIZE CATEGORY 3: 30,000-75,000

City	County	Pop.*
Bakersfield	Kern	69,515
Salinas	Monterey	58,896
Ventura	Ventura	57,964
Thousand Oaks	Ventura	35,873
Santa Maria	Santa Barbara	32,749

SIZE CATEGORY 4: 10,000-30,000

City	County	Pop.*
San Luis Obispo	San Luis Obispo	28,036

TABLE 6.1 (Continued)

SIZE CATEGORY 4: 10,000-30,000 (cont.)

Visalia	Tulare	27,482
Camarillo	Ventura	19,219
Santa Paula	Ventura	18,000
Tulare	Tulare	16,235
Hanford	Kings	15,179

SIZE CATEGORY 5: Under 10,000

City	County	Pop.*
Paso Robles	San Luis Obispo	7,168
M rro Bay	San Luis Obispo	7,109
Carpinteria	Santa Barbara	6,982
Coalinga	Fresno	6,161

*1970 Census

be measured for each city with a compensation Polar Planimeter. Thus, each urban unit will be represented according to the area devoted to each of the mapped land uses.

In order to obtain characteristic spatial population densities for the three residential land use types, 1970 U.S. Census Block Data will be used. Random samples of spatial population density will be taken from areas devoted to each land use in several of the study cities. The range of spatial population densities for each land use is expected to be very nearly the same from city to city. The spatial population density figures obtained from the random sampling will be averaged to obtain characteristic population densities for each residential land use type.

Once the area of each land use type is measured and the characteristic spatial population density of each land use type calculated, the population of an urban area will be computed according to the following simple function:

$$P = A_{R_1} \cdot D_{R_1} + A_{Rm} \cdot D_{Rm} + A_{R_{TP}} \cdot D_{TP}$$

where P = total population; $A_{R_1}, A_{Rm}, A_{R_{TP}}$ = Areas devoted to each land use type; and $D_{R_1}, D_{Rm}, D_{R_{TP}}$ = characteristic spatial population densities associated with each land use type.

6.1.1.2 Analysis of Salinas and Santa Paula, California

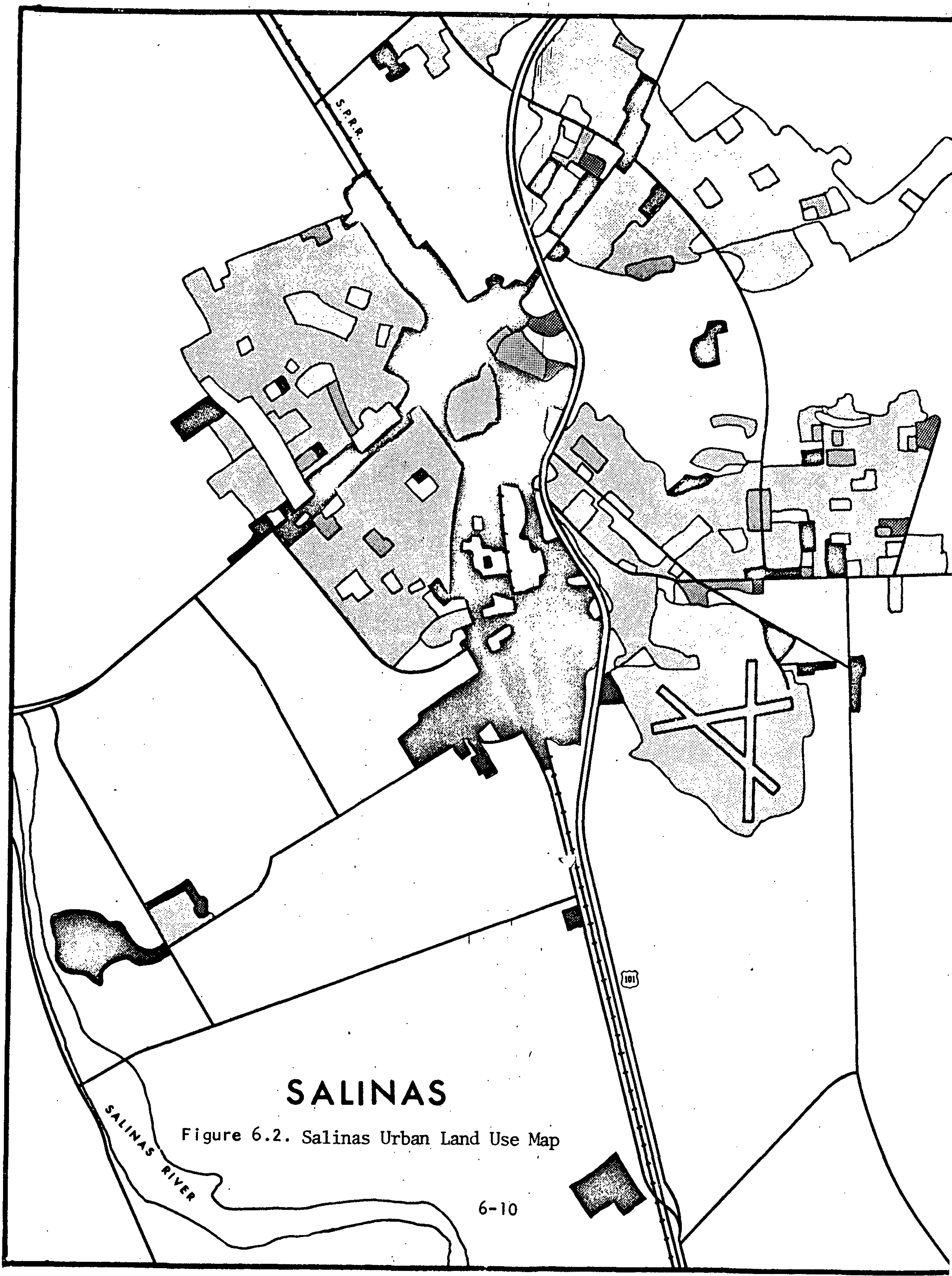
For this preliminary report, two cities have been chosen to illustrate the preceding methodology. The two cities belong to different population size categories: Salinas, with a 1970 population of 59,896 is in Category IV; and Santa Paula, with a 1970 population of 18,001, is

in Category V. Cities from two population size categories were chosen to indicate the application of the methodology under different types of urban situations.

Figures 6.2 and 6.3 show the two cities as mapped according to land use type from the 70mm B & W imagery. Few problems were encountered in the interpretation/mapping process. Supporting information from ground truth field work indicated that the land use maps were generally quite accurate. An exception was that small, isolated apartment units and old houses which have been converted into apartments tended to be underestimated and classified with single family residence (R_1). Table 6.2 shows the measured area in square kilometers of each land use type for both cities.

In order to calculate characteristic spatial population densities for the residential land use types, random subsamples of spatial population densities were taken from five cities of various size categories using 1970 U.S. Census Block Statistics. It was found that the range of spatial population densities for each residential land use type was consistent from city to city and from the various size categories. This supports the assumption that an average, or characteristic, spatial population density for each land use type can be applied to different urban areas. The results of the random subsampling process were averaged to yield the characteristic population densities listed in Table 6.2.

The measured area for each residential land use type was then combined with its corresponding characteristic population density for each of the two cities, according to the previously described mathematical



SALINAS

Figure 6.2. Salinas Urban Land Use Map

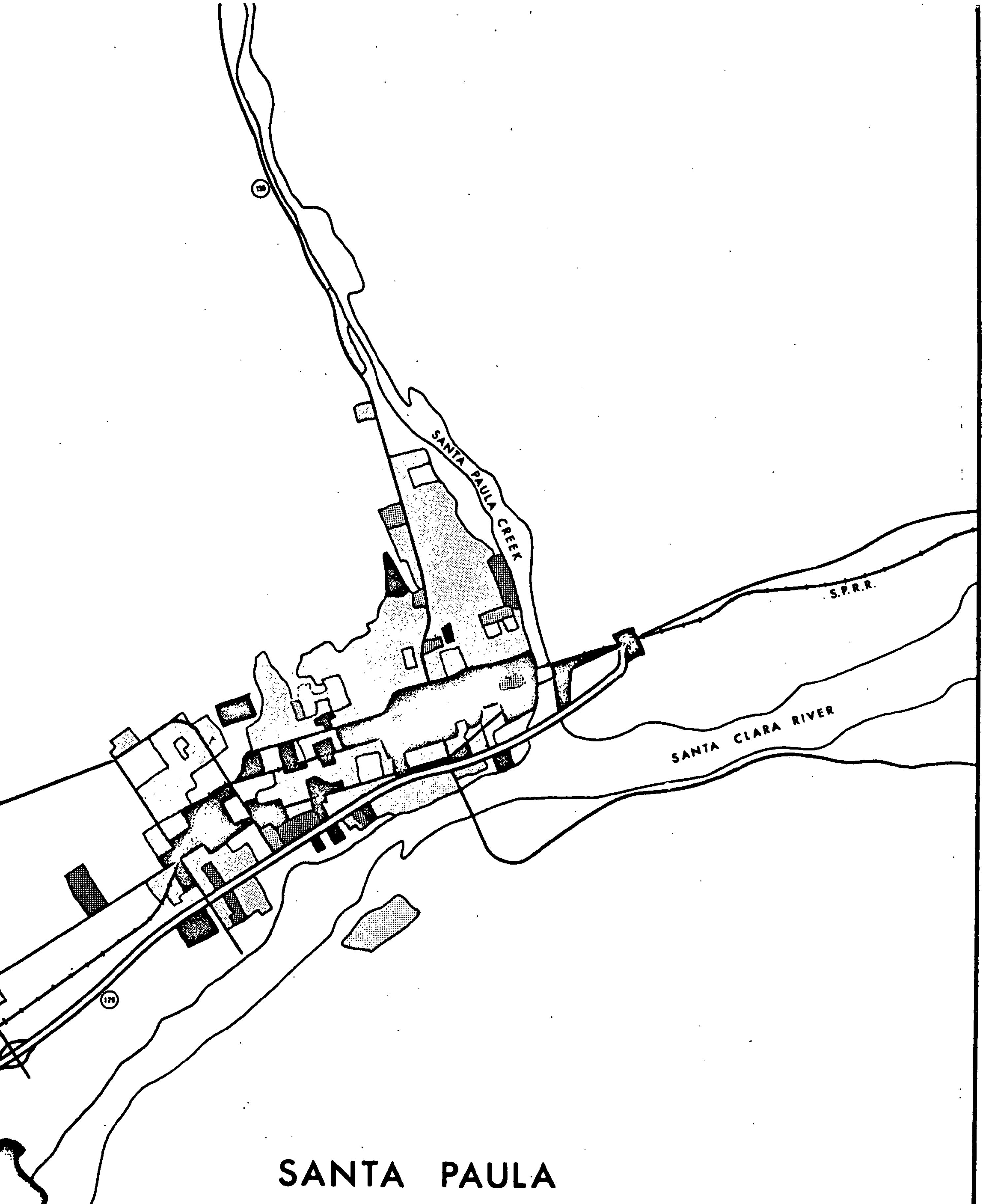
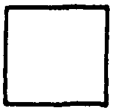
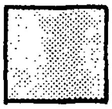
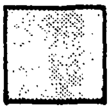


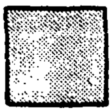
Figure 6.3. Santa Paula Urban Land Use Map

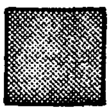
URBAN LAND USE LEGEND

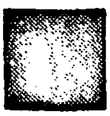
 OPEN SPACE

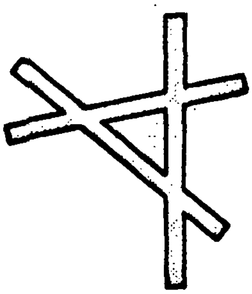
 PUBLIC

 R_1

 Rm

 TRAILER PARK

 COMMERCIAL/INDUSTRIAL

 AIRPORT (PUBLIC)

Figures 6.2 and 6.3 (continued)

TABLE 6.2. POPULATION ESTIMATION DATA

Information Category	Urban Land Use Data			
	Salinas		Santa Paula	
	Measured Area (Km^2)	Spatial Population Density (People/ Km^2)	Measured Area (Km^2)	Spatial Population Density (People/ Km^2)
Single-family Residences (R_1)	12.687	3502	3.910	3502
Multi-family Residences (R_m)	.766	12344	.264	12344
Trailer Parks (T_p)	.152	6449	.214	6449
Commercial (C)	5.897	0	1.447	0

Information Category	Population Data	
	Salinas	Santa Paula
Estimated Population Size	54,866	18,332
Actual Population Size	58,896	18,001
Percent Error	6.84%	1.84%

function. The resulting estimated population was then compared with the 1970 population of each city and the percent error calculated (see Table 6.2).

6.1.1.3 Evaluation

Based on the experience gained in the preliminary test of the proposed method of population estimation, we are optimistic that a generally applicable method for estimating urban population can be developed. The percent error found in the preliminary test in Salinas (6.84%) and Santa Paula (1.84%) was much smaller than the error associated with some other methods (150% error applying Nordbeck's allometric growth function to Handord, California).

The percent error encountered in this preliminary test can probably be reduced through re-examination of the aerial photography to more accurately assign isolated apartment units and old houses that have been converted into apartments to their proper residential land use category. Also, in the case of Salinas, it is possible that multi-family dwellings were underestimated somewhat by mistakenly classifying several large apartments as commercial land use because the apartments were thought to be motels. Further random sampling of spatial population densities in the remaining cities of the larger study should slightly alter the present characteristic spatial population density figures and render them more accurate.

It is anticipated that, with the completion of the larger study of twenty California cities, an accurate and inexpensive method of estimating inter-censal urban population size using conventional aerial photography and U. S. Census data will be developed.

6.1.2 Kern County Cultivated Land Study

6.1.2.1 Objective

The principal objective of this study was to determine the utility of small scale aerial photography for differentiating cultivated cropland and non-cultivated cropland in Kern County. A determination of the amount of cultivated land, in an area where irrigation is important, is needed to ascertain potential for expansion of cultivated acreage, assess requirements for irrigation water, and to assist general planning of the water resources of an area.

6.1.2.2 Procedure and Analysis

The area under investigation was Kern County, California, an area that is heavily dependent on irrigation water for agriculture. With the recent acquisition of water from the California State Water Project, this area will undoubtedly experience expansion of cultivated land. Hence, it is vital that planners have ready access to data relating to the amount of land under irrigation, poorly drained land, etc.

The photography used in this study was NASA color infrared, 70mm high altitude photography (approximate scale, 1:600,000), imaged in 1971.

The first step was to interpret and record, on an acetate overlay, the cultivated and non-cultivated areas in the County. Cultivated land included all land presently under cultivation, cleared pasture land, ploughed land, and land in a bare soil condition. Non-cultivated land included forests and woodland, urban, and extractive activities. Interpretation was carried out visually with the aid of a 8x magnifier. In many instances, interpretation results were checked with NASA 1:120,000 high flight photography.

In the course of mapping, variations were noted in some agricultural areas between very poorly drained land and land under irrigation; the former was eventually classified non-agricultural.

The interpretation data were mapped (see Figure 6.4) and cultivated areas measured, using a planimeter. The resultant figure of 753,369 acres was compared with a Kern County 1969 Crop Survey figure of 746,104 acres of irrigated land, a net difference of 7,265 acres. Selected areas (nodal points) were measured and compared by the Kern County Water Agency. The results obtained indicated that there was an overall error of 3.2% in the data extracted from the high flight photography.

6.1.2.3 Conclusion

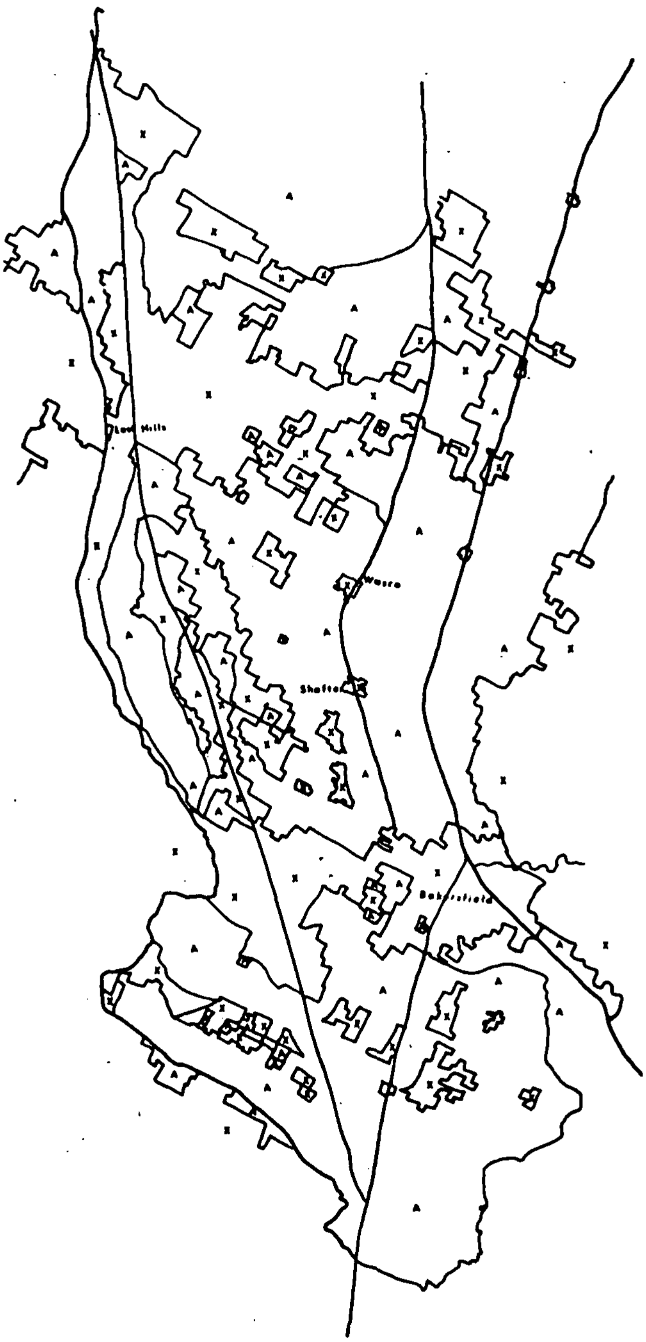
From the results of this study, it can be concluded that high flight aerial photography is a feasible data source for the determination of cultivated and non-cultivated land. It appears, from the Crop Survey figures for certain selected areas, that some poorly drained land had been included under cultivated land. However, if a 1971 Crop Survey of the area were available, it would be possible to determine where and why the photointerpreter and the Crop Survey figures differ. The capability to accurately perform this type of inventory on a yearly basis would be of great importance to planning and management decisions regarding the use of an area's water resources.

6.1.3 West Side Vegetation

6.1.3.1 Introduction

A vegetation map of the West Side has been completed using 1:120,000 scale color infrared photography in conjunction with intensive ground

KERN COUNTY



KEY:

A - Agricultural Land

X - Non-Agricultural Land

Source - 70mm NASA High Flight Photography

Figure 6.4. Kern County Agricultural (Cultivated Land) Land Use Map

reconnaissance and sampling surveys. In addition to the map, descriptions of each vegetation type have been prepared and an effort was made to determine the European land use history with an eye to explaining some of the present day patterns.

6.1.3.2 Methods

The color infrared imagery used for mapping purposes indicated very complicated vegetation patterns. The cultivated areas were easily distinguished owing to their distinctive color and geometry. Riparian and flood plan vegetation were similarly conspicuous. However, spectral responses from the alluvial plains and the lowlands showed considerable internal variation and, consequently, it was not possible to differentiate them without reference to ground truth. Using ground truth data, the vegetation from these zones could then be separated with relative ease. Moreover, many patterns on the photographs did not indicate significant differences in the plant cover, whereas ground reconnaissance revealed communities on both the alluvial fans and within the bottom lands which would not be distinguished on the photographs with any great accuracy. The similar signatures on the photographs were probably due to the close physiognomic and taxonomic relationship of the dominant shrub species in the different communities, and their relatively sparse cover.

The annual community, which covers a much greater proportion of the ground, and is dominated by the same species through large areas, can often be identified on the photography. Where this cover is significantly less, in the lowland areas, it is closely correlated with saline and alkaline soils and a distinct perennial flora. The characteristic spectral response of these areas is probably attributable to the greater exposure

of the bare soil and its distinctive visual characteristics. On alluvial fans, where annual cover approaches 100%, it is not possible to predict with much accuracy areas where the shrub canopy is present or absent. The floodplain vegetation, dominated by mesquite (but also with cottonwood, willow and occasionally sycamore) is readily differentiated and may be mapped quite accurately.

Color infrared photography at the scale of 1:120,000 was found to be the most satisfactory imagery available. No finer distinctions could be made using larger scales (e.g., 1:60,000), while true color imagery, on the whole, displayed a lesser degree of distinction between the vegetation communities. It is believed that the same degree of accuracy, as achieved using 1:120,000 scale, might be as easily attained with still smaller scales.

Having mapped major vegetation boundaries from photography and ground reconnaissance, data were collected to describe the nature of the communities in more detail than presently available. As a large area had to be covered, a rapid sampling method was essential. Reconnaissance indicated that there was very little variation in the vegetation type as distance from the road network increased. Accordingly, it was decided that the road network, which is laid out according to section boundaries or other survey lines, rather than topography, would make satisfactory transect lines. Locations of samples were determined by constructing random lines over the road network and fixing all points where intersections occurred between roads and constructed lines. At these points, samples were taken consistently at a distance of 100 meters from the road sides. The sample transect

consisted of a line of 40 meters in which species occurrence was noted in each square meter. General descriptions were also gathered for each site, and estimates of percent cover were made. However, as field work was done during the summer months after an exceptionally dry season, the degree of deterioration of the annual ground cover was such that a reliable indication of the extent of the cover for the previous winter could not be made. Consequently, the "Winter Annuals" community is not included on the resultant map (see Figure 6.5).

6.1.3.3 Vegetation Types

Desert Saltbush

The desert saltbush (*Atriplex polycarpa*) is the most widespread shrub species on the grazing land of the West Side. It occurs on the alluvial fans, dissected uplands, and the raised sections of the bottomlands along the axis of the valley. Its ability to tolerate saline and alkaline conditions is indicated by its occasional presence on the lowland soils. Only on the better-drained locations does it become the dominant shrub, covering extensive tracts with very few associated shrub species. Typically the community has an almost complete ground cover of annuals, of which filaree (*Erodium sp.*) and brome grass (*Bromus sp.*) are the dominant species (as indicated in Table 6.4).

The degree of dominance of desert saltbush is indicated in Table 6.1, which also reveals there is a great variety in density. Values of presence in each square meter of the 40 meter transect vary from 0 to 32, though in most transects less than 25% of the sub-units contained a shrub (indicating the open nature of the community).

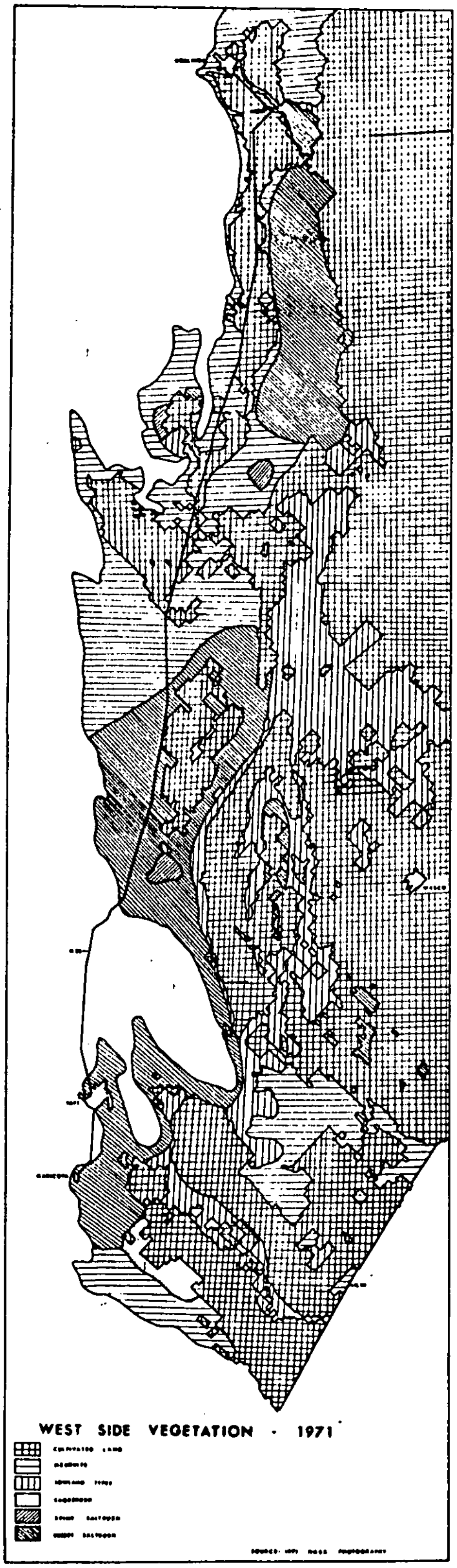


Figure 6.5. West Side San Joaquin Valley Vegetation Communities Map

Key to Tables 6.3, 6.5, 6.6., 6.7, 6.8, 6.9

Tables 6.3, 6.5, 6.6, 6.7, 6.8, and 6.9 show the frequency distribution of dominant flora within the particular vegetation community for forty meter sample transects. The numbers along the left margin of the tables indicate the sample transect. The numbers (1-40) along the top of the tables indicate the specific one square meter blocks which were sampled along the entire length of the transect. For example, Table 6.1 shows the frequency distribution of dominants (perennials) in the Desert Saltbush Community. The degree of dominance of Atriplex polycarpa is evidenced by the high frequency of occurrence of the letter 6 in the table. The absence of letters in some squares indicates the absence of shrubby vegetation within that sample unit, and tends to emphasize the open nature of the community.

Key to letter symbols in Tables 6.3, 6.5, 6.6, 6.7, 6.8, and 6.9:

a Suaeda fruiticosa

b Atriplex polycarpa

c Atriplex spinifera

d Frankenia grandifolia

e Allenrolfea occidentalis

f Distichlis spicata

g Sporobulus airoides

h Haplopappus sp.

i Salsola kali

k Atriplex sp.

l Gutierrezia bracteata

m Artemisia californica

TABLE 6.3. DESERT SALTBUSH COMMUNITY

Sample No.	Meters 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	b	b	b	b			b		b	b	b				b	b				b										b	b	b	b	b	b	b	b	b	b	b
2							b	b									b	b																						
3			b	b	b	b	b	b	b	b	b	b	b	b	b		b	b			b	b	l	l		b	b	b	b	b		b								
4	c															c									c	c		b	b	b		b		b	b					
5				b												b	b	b		b					b	b										b	b			
6	m						b	b																				b	b											
7								b																			b								b	b				b
8																																								
9																			b	b												b	b	b						
10	b	b	b	b	b	b	b	b	b	b	b			b	b			b	b	b	b				b	b	b	b	b	b	b	b	b	b	b	b	b		b	b
11	b	b	b	b	b																					b														
12																	b	b																				b		b
13											b	b	i																						b	b				
14																																								
15								b	b	b										b	b	b																		

TABLE 6.4. GROUND COVER PLANTS IN TWO VEGETATION TYPES

	Desert Saltbush							Winter Annuals													
Sample No.	1	2	13	15	17	26	30	3	4	5	6	7	8	11	14	18	25	27	28	29	3
Bromus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Erodium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Cryptantha	x	x						x	x	x	x		x		x						
Lepidium	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Amsinkia		x	x			x						x		x	x						
Haplopappus		x																			
Setaria								x			x						x				
Compositae 1									x	x											
Compositae 2				x	x				x	x				x	x						
Plantago 1									x												
Gramineae 1					x	x			x	x		x			x			x			
Gilia									x		x										
Leguminosae					x	x			x						x		x				
Gramineae 2										x									x		
Plantago 2						x	x			x	x				x						
Hordeum					x								x					x			
Orthocarpus						x							x								
Gramineae 3														x		x					
Gramineae 4			x												x						
Phacelia			x	x											x						
Brassica			x																		
Gramineae 5			x	x											x						
Euphorbia																x					
Gramineae 6																	x				
Barassica																	x				
Taraxacum						x	x										x				
Compositae 3																	x				
Compositae 4						x											x				
Eschscholzia																		x			
Lupinus																		x			
Trifolium																					

TABLE 6.5. WINTER ANNUALS COMMUNITY

Meters

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1		i																				i																		
2		i								i	i			i	i													i												
3		i	i									i				i			i	i												i			i	i	i			i
4		i							i	i			i									i	i	i	i			i	i	i	i									
5																																								
6			i	i																							i						i		i	i				
7	i	i	i	i	i	i		i			i	i	i					i			i			i			i	i	i	i	i			i						i
8																																		i	i					
9																																								

TABLE 6.6. SAGEBRUSH COMMUNITY

Meters

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1											i																													
2																								m																
3																																								
4																																								
5		m	m		m	m																				m	m													m
6				m																m						m														

TABLE 6.7. SPINY SALTBUSH

Meters

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1																											c	c	c						c		c	c		
2																								c	c	c														
3													c											c	c															
4						c																						i	i		i									
5	c		c	c		c	c	c	c	c	c				c	c	c	c	c				c				c	c	c d	c d	d									

TABLE 6.8. LOWLAND TYPES COMMUNITY

Meters

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1				a	a	a	a	a			a	a									a					a	a			a	a									
2						b	b										a	a	a c	c	c				a				a	a		a	a		a	a		a		a
3																																								
3	a	a	a	a		a	a	a	a		f			a g	a g	g	a d g	a g	g	g				d		e			a d	a d	d g				h	b h	b	d		d
4			a	a	f	f	f	f	f	f																														
5					e	e	a e	a																																
6									h	d h	d									d	a	a d	a d	a	a	a	a	a	a d											
7	f	f	c	c b	f b	f b	f	f			f						b	b				a	a	a			a	a			f	f	a f	a f	a f	b f	b f	b f	b f	b f
8															e	e	e	e	e												e	e	e	e			e	e	e	e
9						a		a	a						a	a												a	a			a	a			c			c	
10	a	a	a	a	a		a	i				a								a																				
11	i	k	d k	a i k	a i k	a i	i	a	i k	i k	a	i	i	i		a		i			a			i	i				i	i		i	i	i	i	i		i		
12	i	i	i	i	i k	k	i k	k	i	i	i	i k	i	i	i	i	i	i	i	i	i	i	i	i	i	i		i	i	i	i	i			i	i		i	i	i

TABLE 6.9. MESQUITE COMMUNITY

Meters

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f			f	f	f	f	f					f	f		f		f	f	f	f
2																																								
3																																				h	h	h	h	
4								h	h	h	h																h													
5																	f		f																					
6					a			a	a	a			a	a																										
7																			c	c	c									g										
7		f	f	f						f		f	f			f														f	f	f								
		a		a	a							a	a		a		a	a	a				a	a		a	a					a	a		a	a	a		a	
			h	h											h																									
								g							g																									

Piemeisel and Lawson (1937) mapped this community, and concluded it was more extensive in pre-European times, having been reduced in areal extent by cultivation, clearing in the oil fields, and grazing activities. The aridity of the West Side south of Coalinga has prevented dry farming, although irrigated cropland which is of recent origin, is presently at its greatest areal extent. Destruction of this shrub community, by crop cultivation followed by abandonment, does not apply to the area under consideration. However, the clearing of shrubs in oil fields to reduce fire risk has undoubtedly occurred. Early photographs of oil fields show bare soil. Where sites could be identified and revisted today, desert saltbush has been able to satisfactorily re-establish, forming communities which are indistinguishable from those not subjected to clearing. This species shows a degree of weediness, as it seems to invade disturbed areas such as construction sites and roadsides where competition is reduced and runoff might be increased. Ranchers are well aware of the regenerative powers of desert saltbush in wet years on land that has been burned or overgrazed.

Field experiments concerned with saltbush regeneration have been conducted on the Temblor Range Experiment Station over a period of years. From these experiments, some important ecological relationships were demonstrated. Strips of range were disced to reproduce conditions of cultivation, and pruned with a cotton harvester, to approximate grazing. The frequency and vigor of plants before and after treatment were compared. Results suggested that cultivation may actually lead to an increase in the shrubs, presumably by removing competition. Pruning on the other hand

led to a deterioration in the perennial shrubs, suggesting that grazing might in this case lead to the reduction of the shrub community to the advantage of the understory of the annual grasses and herbs.

Since the last recorded mapping of this community, in 1935, further contractions in its extent have occurred. The present boundary between this vegetation type and that of Winter Annuals, south of Kettleman City, is marked by areas where 60% of the shrubs appear to be dying or are dead. This suggests still further retreat may be occurring, stimulated perhaps by two consecutive dry years. The present distribution of desert saltbush is confined to the alluvial fans, which are most affected by the rain shadow of the Temblor Ranges, or to dissected anticlinal ridges, where shallow soils and rapid run off would reduce rainfall effectiveness. Only here does this deep rooted perennial seem to have competitive advantage over the aggressive, but shallow-rooted annual grasses and herbs.

Winter Annuals

The community composed of only annual plants shows little structural or floristic difference from that of the understory of the Desert Saltbush vegetation type (see Table 6.4). Although consideration of the annual flora is not within the scope of this study, a brief survey indicates little floristic difference between the two communities. Table 6.4 shows that the most ubiquitous annuals, filaree and brome, were recorded in every sample (in both communities) and in fact probably make up 90% of the biomass of the plant community. No commonly occurring plants are restricted to one or the other of the types.

Both filaree and brome are introduced species (Munz, 1968) which appeared very early in the period of European occupation. Fremont, for example, noted the presence of filaree (Erodium cicutarim) in the Central Valley in 1844 (Fremont, 1845). In more moist regions, it is believed that annuals such as these replaced native perennials. It is unlikely that perennial grasses were an important component of the flora of the southern West Side, as they would not be able to withstand the arid conditions. The pre-European flora, then, was presumably composed of the native grasses which are now of only importance among the understory plants.

Russian Thistle (Salsola kali) is worthy of special mention because it can become a serious weed, and can also adopt a perennial habit. Its frequent occurrence in the Winter Annual areas and its rarity in regions where other shrubs are present, may be a significant relationship, reflecting the pioneer nature of the species and its inability to compete with other perennial plants.

Annual grasslands, as presently constituted, are a post-European phenomenon. However, since 1935, their extent has increased at the expense of the saltbush communities. This is thought to be a result of grazing pressure leading to the destruction of the perennial shrubs in the moister regions where grazing pressure is strongest and where the xerophytic characteristics of the saltbush species have least competitive value.

Sagebrush

This shrub community is similar in structure to others within the study area in that (1) it is dominated by a single perennial plant, the

California sagebrush (_Artemisia californica_); and (2) it has an understory of annual plants composed of the same species with similar relative abundances as do other alluvial fan communities. For this reason, the sagebrush type cannot be differentiated at all on the available photography.

Many historical accounts of the Central Valley mention the "Sagebrush." However, this probably reflects the practice of applying this common name to any grey-green, low shrub, rather than indicating a widespread replacement of _Artemisia_ by other shrubby species over the western rangelands. Earlier surveys noted the occasional presence of sagebrush on the West Side, but nowhere was it noted as a dominant shrub. Hence the present extent of this vegetation type on the alluvial fans of the Tehachapi Mountains may represent a recent spread of the species. On the other hand, it may represent an oversight or have been considered to have occupied an area too small to be mapped.

If the Sagebrush community is a recent invasion, experience elsewhere suggests it may be a result of management practices (Robertson and Kennedy, 1954). Because sagebrush is a poor browse, preferential grazing by cattle tends to increase the abundance of _Artemisia_. The present boundary between Sagebrush and Desert Saltbush types (as discernable on the ground) is a remarkably abrupt one, though it does not correspond to a fence line or any other obvious cultural division.

Spiney Saltbush

This community is one of the most restricted on the West Side. It is dominated by _Atriplex spinifera_ forming a very low and incomplete shrub canopy. Much of the land once occupied by this species is now

under cultivation; hence, it is difficult to determine the original areal extent from the fragments of the distribution which remain. It is probable that the community occupied a zone at the base of the alluvial fans between the Desert Saltbush of the higher slopes and the Lowland Types of the flat bottomland. Soils in this area have some problems associated with poor drainage and high salinity. Other perennial plants occasionally found in this community are those with salt tolerance. The understory of annual plants appears to be adversely affected by the properties of the soil; hence, much land is bare, with some evidence of salt scalds.

The 1935 vegetation map indicates that the community was previously more extensive than today, even on land which is still uncultivated. This explanation may lie partly in the difficulty of defining the community in precisely the same way as Piemeisel and Lawson, since they offered only a descriptive account of the type. However, in 1935 a large section of the southern Kettleman Hills was recorded as dominated by this vegetation type. Today, only a tiny pocket of shrub vegetation exists, which is in poor condition and apparently disappearing. The majority of the area is presently covered by only winter annuals. Grazing pressure is a possible explanation of the retreat of this species. However, the species is considered a poor browse as it is spiney and, unlike desert saltbush, does not produce new growth during summer when range plants are in poor condition.

Lowland Types

This community is by far the most diverse in species content of perennials and annual ground cover. The considerable exposure of the

soil and its strongly saline character are thought to be largely responsible for being able to recognize this community on the photography.

Seep-weed (Suaeda) is the most common shrub, and is only absent in low lying sections, which have conspicuous soil salinity problems, or in the lake beds, where occasional high water levels inhibit the growth of perennial plants. Allenrolfea forms dense stands with no ground cover at all in some poorly drained locations. In the Tulare Lake bed, which is now largely under intensive cotton cultivation or casual barley cropping for hay, saltgrass (Distichlis) and Frankenia appear as weeds in the barley fields, and will predominate when water is not available to flood irrigate the hay crop.

The Lowland Types are little grazed, since the shrubs are unpalatable and the annual ground cover is relatively sparce. In the past, the overflow lands such as these were among the most valuable pastures in the lower San Joaquin Valley. But, with the controlling of the waters of the Kern and Kings Rivers and the diversion of water for irrigation on the eastern side of the valley, the bottomlands which are not cultivated are the least productive in the area.

Mesquite

This community covers the alluvial fan of the Kern River. Near the stream channels, willow, cottonwood, and occasionally sycamore are present, but only mesquite covers extensive areas of the delta. The mesquite develops a so-called running form, where the branches spread laterally, producing a roughly circular thicket perhaps 15 meters in diameter and 5 meters high. Individual trees rarely touch, and owing to

their greater vertical height than the sparse, low surrounding shrub vegetation, they are most conspicuous on the photography. The understory is essentially the same as the Lowland Type, where seep-weed is the dominant. In the immediate vicinity of the drainage channels, weedy species are common in the sandy alluvium of the braided stream course.

The extent of the community has not previously been delineated, though it is the most easily distinguished from either ground or air. This may be a result of the increase in area under mesquite over the last 30 years. The species is not widely recognized as an introduced plant (Munz, 1968; Jepson, 1936; Twisslemān, 1967). Spanish missionaries commonly made mention of the cottonwood and willow in the Kern River area (Cook, 1958), but made no mention of mesquite, today the most common tree. The early American explorers record the same picture. The earliest mention of mesquite in the San Joaquin Valley is a reference in a newspaper article written in 1877 and quoted in Tracy (1962). The earliest botanical collection appears to be one made by Burtt Davey in 1896 (No. 1756), suggesting the species had invaded the valley at least by the late nineteeth century. The dispersal of mesquite over extensive areas of the Southwest is considered to be at least in part the result of grazing practices. It is hard to imagine that mesquite could not disperse naturally from the Mojave in pre-European times. Presumably grazing practices rendered the area suitable for establishment of seedlings.

In recent years the declining water table, resulting from increased pumping for irrigation, has caused deterioration of the floodplain vegetation. As early as the 1850's, early American explorers noted extensive

areas of dying cottonwoods, probably owing to some natural readjustment of drainage and underground water supplies. With additional water from the California Aqueduct, it is expected that the water table will be stabilized at a level higher than present. The effect of this may lead to further spread of mesquite, at present controlled by the dry conditions.

6.1.3.4 References

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6.1.4 Coastal Zone Investigation

As part of the three campus (Berkeley, Riverside, Santa Barbara) integrated study of the California Coastal Zone, the Geography Remote Sensing Unit is responsible for the portion of this area extending from Santa Monica in the south to Monterey in the north (see Figure 6.6).

The objective of the overall study is the development of a standardized, multi-functional data base for the entire coastal zone. Elements of the data base will include parameters such as land use, landforms, natural vegetation, hydrologic features, etc. A data base of this nature will prove invaluable for resource inventories, anticipation of future urban pressure and movement, service needs, optimum open space elements, planning hazards (i.e., areas of possible flooding and fire), and general planning and management requirements.

The investigation is being conducted in two phases. The first phase involves the development of classification systems for categorizing characteristic parameters in the Coastal Zone. The second phase concerns mapping and testing the classification systems for intensive areas within the Coastal Zone. As a result of Phase II, a series of maps will be produced for the entire Coastal Zone that will include those parameters needed for a suitable data base.

The first phase has been completed through the coordinated efforts of the three campuses. Significant parameters have been identified for which data need to be collected. These include: land use, landforms, natural vegetation, hydrology, slope, and geology. Working classification schemes for mapping these parameters have been developed and form the basis for Phase II testing. These systems have been designed to meet three criteria: (1) the categories should be appropriate for collecting data within the Coastal Zone; (2) categories should be compatible with the capabilities of remote sensors to provide data and require minimal use of supplemental information sources; and, (3) classification structures should

be hierarchal (proceeding from very general to very specific information categories) to reflect and accommodate changes in data provision capabilities owing to the use of varying sensor platforms. Tables 6.10 and 6.11 illustrate classification structures being tested for land use and natural vegetation.

Two intensive areas are being investigated by GRSU to test the various proposed classification systems (see Figure 6.6). The first area (lower test site) extends from the Oxnard Plain in the south to Gaviota in the north. The second area (upper test site) extends from the Santa Maria River in the south to San Simeon in the north. The inland width of both areas is approximately 24 to 32 kilometers. Mapping is being accomplished from 1:200,000 scale color infrared high flight imagery. Direct overlays are being used to extract data. Preliminary indications are that the land use and natural vegetation classification systems are compatible with high flight data, while some modifications will probably have to be made in the systems for hydrology, geology, slope, and landforms.

6.1.5 Goleta Valley Land Use Change

As an example of the possible applications of a Coastal Zone data base, a study of land use change in the Goleta Valley is being conducted. It illustrates the significance of a data base which is periodically updated to reflect the effects of change processes. Land and its usage are subject to change as a result of the actions of various natural and cultural processes. The geologic processes are slowest, nearly imperceptible; the biologic processes are faster, but less effective in changing land and the uses of the land. Cultural processes are rapid, and can cause large scale changes

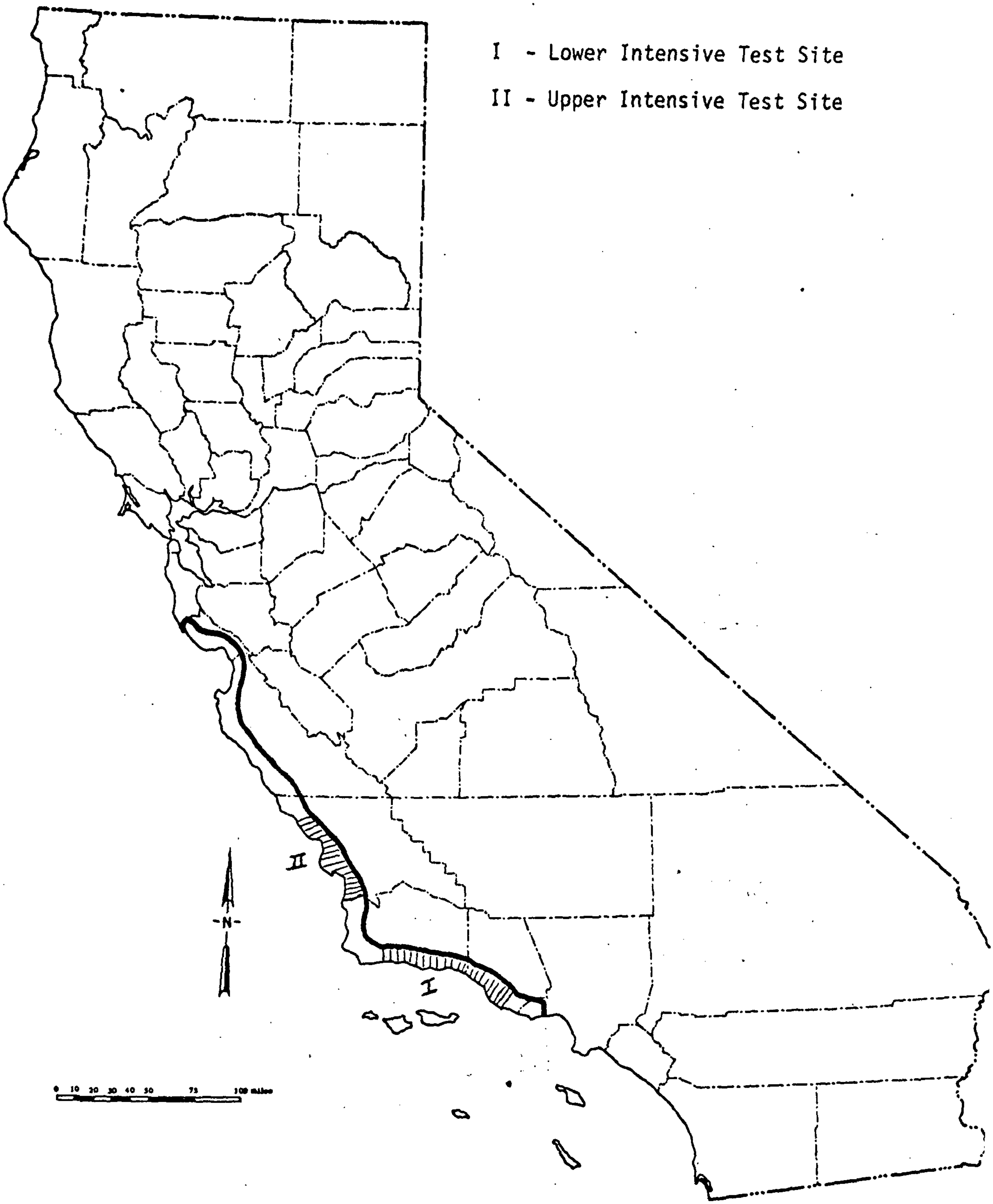

Figure 6.6. Central Coastal Zone

TABLE 6.10. LAND USE CLASSIFICATION

KEY:

General Category ex. A (Agriculture)
Type within Category ex. t (tree crops)
Specific Type ex. c (citrus)
Total Code: Atc

Note that the more specific notation depends upon ability to identify and additional types and specific types can be added to the system as they are encountered.

	CODE
Agriculture	A
Crops	Ac
Grain Crops	Acg (type)
Horticulture	Ach (type)
Row Crops	Acr (type)
Tree Crops	Act (type)
Livestock	Al
Stock farming (beef)	Alsb
Stock farming (sheep)	Alss
Stock farming (dairy)	Alsd
Rangeland	Ar
Pasture (improved)	Arpi
Pasture (unimproved)	Arpu
Extractive	E
Seawater mineral recovery	Es (type)
Petroleum production fields	Ep (type)
Mining Operations	Em (type)
Public Facilities	G
Governmental-administrative	Ga (type)
Governmental-military	Gm (type)
Cemeteries	Gc

TABLE 6.10 (Continued)

	CODE
Protection- Police & Fire	Gf (type
Hospitals	Gh
Prisons	Gp
Waste disposal (solid & liquid)	Gd (type)
Education	Ge (type)
Parks & Recreation	P
Campground	Pc
Golf Course	Pg
Park	Pp
Stadium	Ps
Marinas	Pm
Resort	Pr
Industrial	I
Primary Conversion	Ip
Steel mill	Ips
Ship building	Ipb
Saw mills (or pulp)	Ipw
Assembly	Ia
Auto	Iaa
Electronic	Iae
Food Processing	If
Canneries-fish	Ifc
Canneries-fruit	Iff

TABLE 6.10 (Continued)

	CODE
Storage	Is
Port warehousing	Isp
Rail warehousing	Isr
Transportation	T
Airports	Ta (type)
Highways	Th (type)
Railroads & Yards	Tr (type)
Canals	Tc (type)
Docks	Td
Commercial	C
Clustered	Cc (type)
Strip	Cs (type)
Residential	R
Single family	Rs
Multi-family	Rm (type)
Non Developed	N
Natural Vegetation	Nv (type)
Idle Land	Ni (type)
Barren Land	Nb (type)
Water Bodies	Nw (type)

TABLE 6.11. NATURAL VEGETATION CLASSIFICATION

Plant Community	Code
I. Aquatic	
A. Marine (Aquatic)	M
1. Nearshore (Kelp and seaweed)	Mn
2. Intertidal	Mi
B. Freshwater (Aquatic)	Fw
C. Marsh	Ma
1. Salt Marsh	Ma_{sm}
2. Freshwater Marsh	Ma_{fm}
II. Terrrestrial	
A. Barren	Ba
B. Strand	Sr
C. Grassland	G
1. Coastal Prairie	Gcp
2. Valley Grassland	Gvg
3. Meadows	Gme
D. Woodland-Savanna	Ws
E. Scrub	S
1. North Coast Shrub	Snc
2. Coastal Sagebrush (soft chaparral)	Scs
3. Cut-over Forest	Scf
4. Chaparral (hard chaparral)	Sc
5. Scrub-Hardwood	Shw
F. Forest	F
1. Hardwood	Fhw
2. Mixed Evergreen	Fme
3. Coniferous	Co
a. Redwood	Co_{rw}
b. North Coast	Co_{nc}
c. Douglas Fir	Co_{df}
d. Pine Cypress	Co_{pc}
G. Riparian	R

TABLE 6.11. (Continued)

DESCRIPTION

I. Aquatic

A. Marine Aquatic- contains vegetation such as kelp, seaweed, algae extending from the intertidal zone to approximately one-half mile offshore.

1. Nearshore (kelp & seaweed)
2. Intertidal

B. Freshwater Aquatic- generally floating vegetative types in lakes and ponds (e.g., algae)

C. Marsh- grassland on wet mineral soil.

1. Salt Marsh- comprised of low herbs and shrubs with some perennial grasses and occur in narrow areas of tidal lagoons, salt marshes and intertidal mudflats, sheltered from pounding surf.
2. Freshwater Marsh- vegetation consists basically of grasses and rushes growing in river or freshwater spring- fed lowlands, from sea level to 500 feet.

II. Terrestrial

A. Barren- contains no vegetative cover

B. Strand- consists of low prostrate vegetation (often succulent perennials) growing on sandy beach or dune areas.

C. Grassland- grasses or sedges dominant; woody plants lacking, seasonal, non-irrigated pasture or range.

1. Coastal Prairie (North Coast Grassland)- temperate grassland containing bunchgrass, flowering herbs and introduced European grasses.
2. Valley Grassland (South Coast Grassland)- basically a sub-tropical, open grassland ranging southward from lower Monterey County.
3. Meadow- isolated grassy pockets in high relatively moist, mountain areas.

TABLE 6.11. (Continued)

D. <u>Woodland- Savanna</u>

E. <u>Scrub</u>- open communities of medium-sized shrubs to 6 feet; woody plants closely spaced.

1. North Coast Scrub- varies from thick to open shrubland with an admixture of grasses. Often occurs between the Strand and Redwood forest.
2. Coast Sagebrush- low Shrubs (one to five feet) with some slightly taller and woodier examples. Less dense than Chaparral but ground cover is, nevertheless, fairly continuous.
3. Cut-over Forest- mainly secondary scrub vegetation in logged areas now in the process of returning to forest.
4. Chaparral- vegetation occurs as dense cover of shrubs from 3-15 feet tall (mainly evergreen, broad-leafed sclerophylls) growing on rocky, gravelly, or fairly heavy soil above the coast sagebrush community.
5. Scrub- Hardwood- dense to open vegetation containing deciduous and semi-deciduous shrubs and low trees.

F. <u>Forest</u>

1. Hardwood- contains homogeneous or mixed stands of hardwood species (i.e. mixed laurel- oak forest, madrone, eucalyptus, etc.)
2. Mixed Evergreen- consists of evergreen and deciduous trees with coniferous and broadleafed species represented.
3. Coniferous- homogeneous or mixed stands of coniferous species.
   a. Redwood- dominated by redwoods in dense forests of very tall trees (up to 350 feet).
   b. North Coast- dominated by Sitka Spruce and Lowland Fir (150-200 feet) in dense continuous forests.
   c. Douglas Fir- dense forests with trees up to 200 feet. Often located up-slope from redwood forests.

TABLE 6.11. (Continued)

d. Pine/Cypress- relatively dense forests of low to medium height (30-100 feet) evergreen needle trees.

G. Riparian- comprises tree and herbaceous growth (generally phreatophytic) along river and stream courses.

in the landscape. The impact of decisions affecting the use of land is not only confined to the specific area of change but also has long-term regional effects. The land changes, and the region reflects the change in terms of economics, aesthetics, and productivity.

The present study is a look at the Goleta Valley area between San Roque Creek, on the East, and Dos Pueblos Creek, on the West. For the years 1961 and 1967, large scale aerial photos were combined to form photo-mosaics. For 1971, much smaller scale photographs were used. Land use categories were mapped on a transparent mylar sheet covering the photos. The objectives for constructing the maps included: (1) determining the acreage in each major category of land use; (2) documenting significant changes in land use over the time periods involved; and, (3) inferring, if possible, the significance of land use changes to the Goleta Valley area.

Table 6.12 lists the total acreage of each major category of land use found in the Goleta Valley for the years 1961, 1967, and 1971. The total amount of agricultural acreage dropped by one-third in the 10 years between 1961 and 1971. Total row crop acreage actually rose, however. This situation may be explained if one considers that land which is "under pressure" from urban expansion does not warrant the investment necessary to start an orchard. Row crop production is more profitable in the short run, and allows the land owner to return a crop profit and sell the land at any time without substantial loss. It is land not previously used for agriculture which has accounted for the increase in row crop acreage. Tree crop areas have gone directly

TABLE 6.12. Goleta Valley Land Use

	Area in Acres			
Land Use Category	1961	1967	1971	Net Change
Tree Crops (Act)	5,155	3,222	3,085	-2,070
Row Crops (Acr)	835	1,068	1,046	+ 211
Other Cropland	101	63	51	- 50
Pasture (Arpu + Arpi)	2,031	1,253	No Data	- 778
Single-family Residence (Rs)	1,905	3,159	4,456	+2,551
Low Density Residences (Rs)	1,218	2,002	1,770	+ 552
Multi-family Residence (Rm)	224	343	475	+ 251
Commercial and Industrial (C+Cc+I)	356	583	1,044	+ 688
Total Agriculture	6,091	4,353	4,182	-1,909
Total Pasture	2,031	1,253	No Data	- 778
Total Residence	3,347	5,504	6,701	+3,354
Total Commercial and Industrial	356	583	1,044	+ 688

into residential and commerical use, as have some row crop acreages and a large number of formerly idle lands. In the 10 year period, total residential acreage has doubled and commercial-industrial acreage has tripled.

The change in land use discussed here occurred over a period of 10 years. But the value of remote sensing in studying the Goleta Valley is not limited to monitoring the change. Perhaps even more valuable would be to integrate remote sensing information into the Environmental Planning process for the region. Anticipation of future urban pressure and movement, of service needs, optimum open-space elements, planning hazards (i.e., areas of possible flooding and fire), and similar planning problems can be accomplished with the appropriate use of remote sensing techniques.

6.2 FUTURE PROPOSED WORK

The Geography Remote Sensing Unit at the University of California, Santa Barbara proposes to conduct several investigations for the coming fiscal year. These include: (1) completion and evaluation of the data base for the Central Coastal Zone of California; (2) continued monitoring of changes in the environment of the West Side of the San Joaquin Valley; (3) completion and evaluation of a method for inter-censal estimation of urban population size; and, (4) construction of a detailed land use map for the Tri-County area (San Luis Obispo, Santa Barbara, and Ventura counties) of the Central Regional Zone.

Phase I of the Central Coastal Zone data base investigation, development of classification systems (land use, landforms, vegetation, etc.) and

interpretation techniques, has been completed. Phase II, compilation of the data base and evaluation of the results, is in the initial stages. During the coming year, Phase II will be completed and provide a well-documented historic baseline for monitoring change in the dynamically growing Central Coastal Zone. Continued monitoring of the Central Coastal Zone will permit subsequent evaluation of the utility of remote sensing data as an information source for assessing the implications of change on both regional environmental quality and area-wide planning.

Investigations of resource parameters that are significant to the regional transformation process on the West Side of the San Joaquin Valley will be continued. The development of an agricultural region is a long-term process that is poorly understood. Remote sensing data are being, and will continue to be, used as historic documentation of the process, and as input for a subsequent model of the agricultural regionalization process. Studies focus on land use change, urban change, population growth, vegetation resources, and short-term problems that may have long-term implications (e.g., salt water intrusion in local water supplies). The studies will prove significant for future resource management and planning.

An investigation into the development of a simple and reliable method, using remote sensing data, for inter-censal estimation of urban population size was initiated during this reporting period. A total of 20 urban sites in the Central Regional Zone are being studied. Preliminary findings indicate that the method being tested shows a great deal of promise. Research during the next year would complete the study and analysis of the 20 sites,

and provide a solid statistical basis for assessing the utility of the method under investigation. The methodology will be of great significance to urban and regional planners at all governmental levels, since existing methods are totally inadequate (on a time and cost basis) for providing this now urgently needed information.

Finally, a new investigation is proposed which would concern the construction of a detailed land use map of the Tri-County area (San Luis Obispo, Santa Barbara, and Ventura counties) in the Central Regional Zone. These counties represent the most rapidly changing areas within the Central Regional Zone, and are the areas having the greatest need of accurate and up-to-date land use information. Close cooperation with local county planners will be maintained during the investigation in order to fully assess the value of this type of land use data, generated from remote sensing techniques, in the county planning process and for determining the relationship between development and maintenance of environmental quality.

Chapter 7

ENVIRONMENTAL MONITORING AND ASSESSMENT IN SOUTHERN CALIFORNIA USING REMOTE SENSING TECHNIQUES

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7.1 INTRODUCTION

Research progress at the University of California, Riverside, supported by the NASA "Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques," is reported herein for the period since May 1, 1972. Efforts consist of remotely sensed data applications which contribute to a better understanding of southern California's resources and environment. Early research focus was limited to assessment of the impact of the California Water Project, but the present report is indicative of the increased scope of investigations supported by NASA. This report contains synopses of work being carried out at various locations by a number of researchers.

7.1.1 Recent Data Acquisitions

The successful continuation of our investigations has been greatly aided by the periodic receipt of photographic overflights of the southern California test area made by NASA. Since completion of data acquisition from Mission 164, significant new imagery has been obtained from a variety of sources. The prime source of imagery has been NASA, but private contractors have flown two missions -- a short, large scale

flight over Cajon Pass -- and an extended series of passes over selected portions of the Mojave Desert (in conjunction with the Dry Lands Institute). Costs for these flights prevent sequential missions from being undertaken, and therefore, photographs received and anticipated from NASA are vitally important for our continued monitoring of southern California's desert resources.

Tables 7.1 and 7.2 list all the imagery received since the termination of Mission 164 flights (April 1971). The flights listed in Table 7.1 include 70 mm and 9 x 9" positive transparencies, flown by the U-2. All are within the southern California test site area, with selected flights concentrating on the urban parts of the Los Angeles Basin. Two other flights extend coverage beyond southern California to the Central Valley and into the San Francisco Bay area. Despite the small scale (1:450,000) of the 70 mm photography, it is of high quality and will be very useful as supporting data for ERTS-1 and preparation for ERTS-B and SKYLAB. All bands have good exposures and resolution useful for both rural and urban areas, although some multiband photography has been poorly copied.

The 9" x 9" transparencies represent the best imagery received to date. Not only are the color processing and resolution excellent, but the exposure settings, especially over desert areas, allow more detailed interpretation than has previously been possible. It also opens the way for very high quality, and perhaps quantitative correlation with ERTS-1 and ERTS-B data. The RC-10 and 70 mm package contained on these U-2 missions shows definite superiority over the comparable RB-57 sensors used during Mission 164.

TABLE 7.1. POST MISSION 164 U-2 PLATFORM

Accession Number	Sensor ID Number	Flight Number	Date	Area
		70 mm Format		
00005	001	71-025	9-1-71	Southern California Test Site
00006	002	"	"	
00007	003	"	"	"
00008	004	"	"	"
00041	002	71-036	9-24-71	"
00042	003	"	"	"
00043	004	"	"	"
00058	001	71-048	10-14-71	"
00059	002	"	"	"
00060	003	"	"	"
00061	004	"	"	"
00116	001	71-067	11-24-71	"
00117	002	"	"	"
00118	003	"	"	"
00119	004	"	"	"
00140	001	71-075	12-9-71	"
00141	002	"	"	"
00142	003	"	"	"
00143	004	"	"	"
00194	001	72-020	2-3-72	"
00195	002	"	"	"
00196	003	"	"	"
00197	004	"	"	"
00198	001	72-024	2-17-72	"
00199	002	"	"	"
00200	003	"	"	"
00201	004	"	"	"

TABLE 7.1. (CONTINUED)

Accession Number	Sensor ID Number	Flight Number	Date	Area
00214	001	72-035	3-3-72	Southern California Test Site
00215	002	"	"	
00216	003	"	"	"
00217	004	"	"	"
00248	001	72-049	3-28-72	"
00251	004	"	"	San Francisco Bay
00264	001	72-054	3-31-72	Southern California Test Site
00265	002	"	"	
00266	003	"	"	"
00267	004	"	"	"
		9" x 9" Format		
00460	017	72-101	6-16-72	Mojave Desert
00498	"	72-112	7-11-72	Southern California Test Site
00575	"	72-130	8-1-72	

TABLE 7.2. ERTS FRAME SUMMARY BY PERIOD - 1972

	9.5 Inch Positive Period						70 mm Positive Period						70 mm Negative Period					
Frame	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1						11/5						11/5						11/5
2			9/12			11/5						11/5						11/5
3	8/7	8/25	9/12	9/30		11/5						11/5	8/7	8/25	9/12	9/30		11/5
4	8/7												8/7					
5						11/6						11/6						11/6
6		8/26	9/13	10/1		11/6						11/6		8/26	9/13	10/1		11/6
7		8/26	9/13	10/1		11/6						11/6		8/26	9/13	10/1		11/6
8				10/1												10/1		
9																		
10			9/14	10/2											9/14	10/2		
11			9/14			11/7						11/7			9/14			11/7
12																		
13																		
14	8/10					11/8						11/8	8/10					11/8
15	8/10		9/15			11/8						11/8			9/15			11/8
16				10/3		11/8						11/8				10/3		11/8
17	8/11												8/11					
18		8/29		10/4	10/22									8/29		10/4	10/22	

Table 7.2 lists all ERTS-1 imagery received as of December 19, 1972. Images of earlier passes of the satellite were found to be wanting, by comparison, to later passes, particularly period 6. Primitive reproduction and enhancement techniques have allowed reasonably detailed preliminary analysis of both rural and urban phenomena; period 6 imagery proved far better than earlier passes for interpretation of urban areas. It is anticipated that, if the quality remains consistently good, some valuable information and techniques may be developed and modified through the use of ERTS data.

Earliest 70 mm negatives of the ERTS-1 imagery were found to be too dense to allow prints to be made. Like the positivies, the negatives from period 6 are better and are quite adequate to the task. Preliminary examinations have revealed some productive uses for this sequential type data, despite the fair to poor quality of the earlier data.

7.1.2 Assistance Given to Others

The UCR research group has consistently maintained a policy of availability and assistance with respect to the data and techniques developed and housed here. Being associated with a university, it is our function to aid progress in the education of not only students, but of people outside the university community as well. Over the past year, substantial numbers of people have inquired about remote sensing, and the research conducted at UCR. There have been nearly as many types of questions and problems as people asking them. Such inquiries have come from a wide variety of businesses, institutions and governmental agencies, and have been introduced to new data and techniques which they might find useful. Table 7.3 lists the origins of these visitors and the wide array of subjects which they wished to discuss.

TABLE 7.3. INFORMATION AND APPLICATIONS ASSISTANCE

I. Origin of Visitor

A. Academic

1. Faculty

a) University of Montana

b) University of California, Riverside

c) University of Wisconsin

d) University of Southern California

e) California State University, Fullerton

f) San Diego State University

g) University of California, Los Angeles

h) Cal Poly, Pomona

i) University of California, Santa Barbara

j) Rio Hondo Junior College

k) San Bernardino Valley College

l) Riverside City College

m) Pierce Junior College

2. Students

a) UCR (Anthropology, Geology, Business Administration, Sociology, Political Science, Biology, Plant Sciences, Soils, Urban Studies, and Dry Lands Institute)

B. Government Agencies

1. City

a) Department of Water and Power, Los Angeles

b) Department of Parks and Recreation, Los Angeles

c) Riverside City Planning Department

2. County

a) Los Angeles County Planning Department

b) Los Angeles County Parks and Recreation

c) Riverside County Planning Department

d) San Bernardino County Planning Department

e) Orange County Planning Department

3. State

a) Department of Water Resources

b) Department of Highways

c) Department of Parks and Recreation

4. Federal

a) Bureau of Land Management

b) NASA (Goddard)

c) Bureau of Reclamation

d) USDA

C. Private

1. Southern California Testing Labs

2. Davidson Engineering

3. Doubleday and Company

4. Los Angeles Times

5. Environmental Systems Research Institute

II. Types of Assistance

A. Philosophy and Uses

B. Introduction to Remote Sensing Technology

C. Sensors and Processing

D. Techniques and Methods

E. Automated Interpretation and Mapping

F. Classroom and Instructional Aids

G. Bibliographic Aid

H. Subjects Analyzed

1. Land Use
2. Natural Vegetation and Wildlife Habitat
3. Geomorphology
4. Urban Growth
5. Environmental Impact Studies
6. Real Estate Development
7. Recreation
8. Statistics on Newcastle Disease
9. Regional Planning
10. Environmental Hazards
11. Environmental Perception

I. Coordination on Projects (BLM on-off road vehicle analysis)

Clearly, our function has ranged from describing the philosophy and general uses of remote sensing and satellite platforms to assistance in detailed analysis of complex environmental problems using larger scale photography. The fact that requests come from academic, governmental and private groups reflects the importance of the research occurring and the kind of favorable public relations which come naturally with the growing association between the university and non-university

researchers and users' worlds. Undoubtedly, continuing research of this sort will hasten the acceptance of the technology and will ultimately result in positive social benefits as these techniques are used in evaluating and solving environmental problems.

7.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

7.2.1 Regional Information Systems

The development of equipment and methodologies for geographical information systems is a major topic of investigation at the University of California, Riverside. These investigations and developments have, for several years, been supported by sources other than NASA. Because of the successful applications of the information system equipment and techniques being developed, and due to increasing need for the present and future investigations to handle large quantities of regional data, it is important that the two studies increasingly be more closely integrated. Several of the present studies, reported herein, have already made use of the system to various extents.

An earlier technical report by Nichols, "A Demonstration of the Use of the Grid System Utilizing Multi-Source Inputs," is mentioned in the present discussion because it represents a primitive framework in which the relevant uses of remotely sensed data in a geographic information system can be viewed. Nichols' study is based on the use of NASA photographic data (Mission 128B) and applies important concepts to a portion of the study area for NASA-sponsored investigations being conducted at the University of California, Riverside.

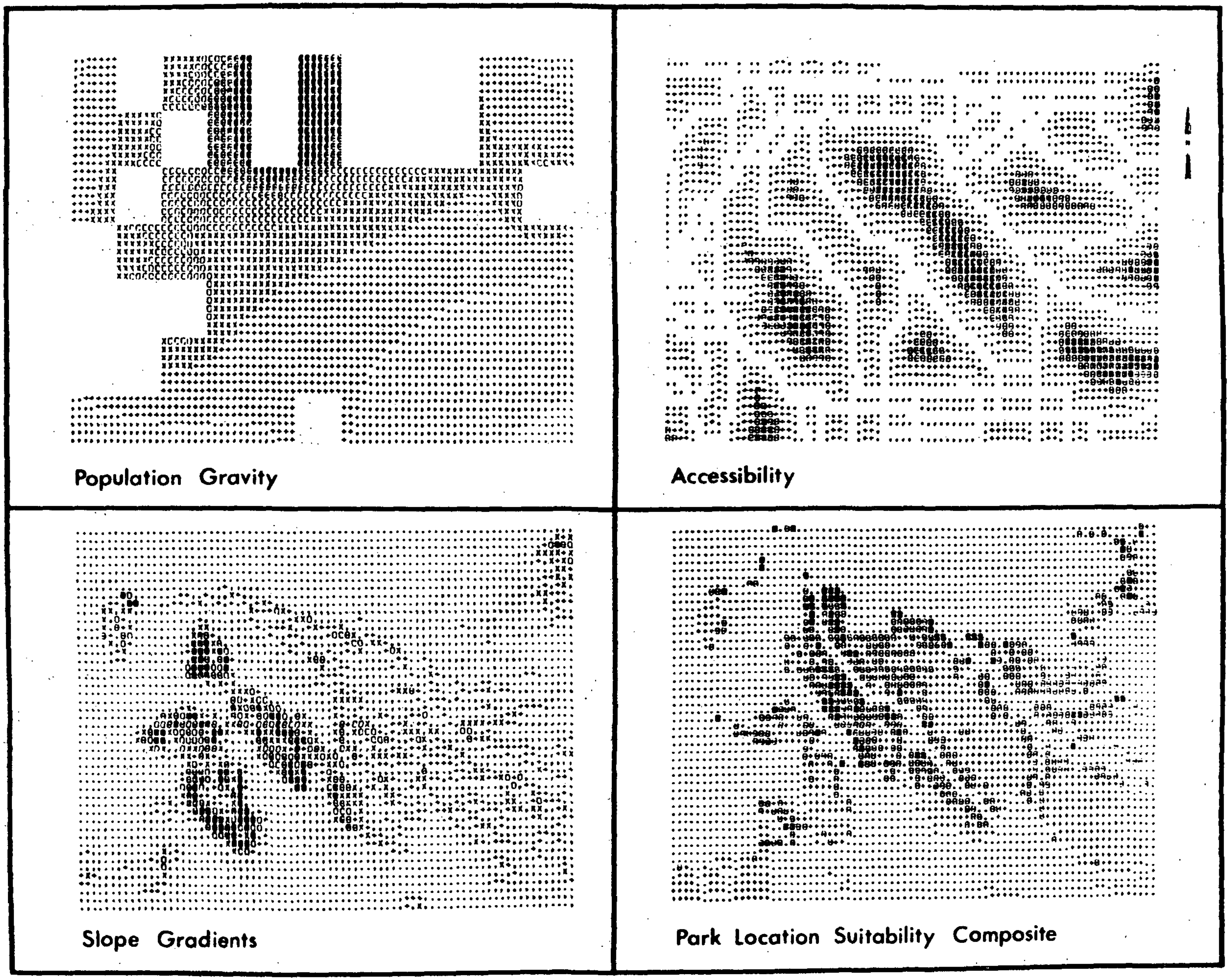


Figure 7.1. Data Integration using a grid cell digital system.

Nichols demonstrated the use of a grid cell digital system when seeking to integrate data derived from high altitude aerial photography (simulated spacecraft data) with other sources of information, e.g., topography, geology, vegetation, transportation, land use, etc. The system has the capabilities of data storage, retrieval, and manipulation. Further, a regional data bank file possessing spatial characteristics can be displayed with computer graphics and manipulated in the computer. For regional information systems to utilize as input any remotely sensed data, two primary factors must be considered: resolution and regionalism. Obviously, the two needs are ambivalent; consequently a compromise which minimizes the adverse effects of both must be sought

7.2.1.1 Information Systems and Resource Management

Under NASA support, research has expanded. Using a full systems approach, researchers are continuing to develop a methodology which would allow complete data input and information output for all resource management situations. This work, by Nichols and Brooner, was published as Technical Report T-72-3 and was jointly supported by Project THEMIS and NASA. The report, "Interfacing Remote Sensing and Automated Geographic Information Systems," utilized previous experience and addressed the entire process of combining remote sensing technology with automated geographic information systems.

The following discussion presents a scheme for utilizing remote sensing technology in an operational program for regional land use planning and land resource management program applications. The scheme

is not absolute; rather, it provides a framework and a structure which allows for many considerations and variables and necessary augmentation, through time and experience, that are required in any dynamic, operational program. The scheme utilizes remotely sensed data as one of several potential inputs to derive desired and necessary information. Several alternative approaches to the expansion and/or reduction and analysis of data using automated data handling techniques are considered. This discussion begins with the decision to utilize remotely sensed data for a land resource program, and is inclusive of the applications and considerations of analyses and products useful to variable levels of decision and policy. Within this scheme is a five-stage program development: (1) Preliminary Coordination, (2) Interpretation and Encoding, (3) Creation of Data Base Files, (4) Analysis and Products, and (5) Applications.

Stage I - Preliminary Coordination

First, one must assume that: (1) a regional land use or resource management program exists, (2) there is both a recognized need and desire for relevant environmental data, and (3) remote sensing technology has been selected as a tool to provide environmental data relevant to the program objectives and problems. One then considers the choice of remotely sensed imaging systems to be employed. In reality, there may not be a choice of imaging systems due to costs or limited availability. For example, regional planners are often limited to existing black-and-white photography or conventional aerial photographic surveys which utilize low and medium altitude black-and-white

or color negative films. Hopefully, considerations for choosing the sensor and its specifications would include application criteria, landscape parameters, and sensor parameters. An organization of preliminary coordination considerations is shown in the flow chart.

Stage II - Interpretation and Encoding

Stage II of the scheme for utilizing remotely sensed data is referred to as Interpretation and Encoding. Within this stage, the remotely sensed data are interpreted, extracted, and related to the computer data base along with various exogenous data. All data are encoded in a digital format which allows further data analysis to be made in subsequent stages of the system. Depending on the techniques employed in the various phases, the Interpretation and Encoding stage may be simple or complex, as can be seen by some of the individual considerations presented in the discussion.

The options and sources for the dissection and dissemination of environmental data confront the image interpreter with alternatives which must be decided upon in order to determine subsequent data handling means. Automated interpretation of remotely sensed images (e.g., pattern recognition) is a process which is still in the research stage and is not extensively considered in the present discussion. With the increasing amounts of regional data being provided from platforms such as high altitude aircraft, or ERTS-type satellites, the potential for implementation and use of automated interpretation systems becomes more attractive. Manual interpretation of remotely sensed images can be transcribed by various methods. First, mapping directly

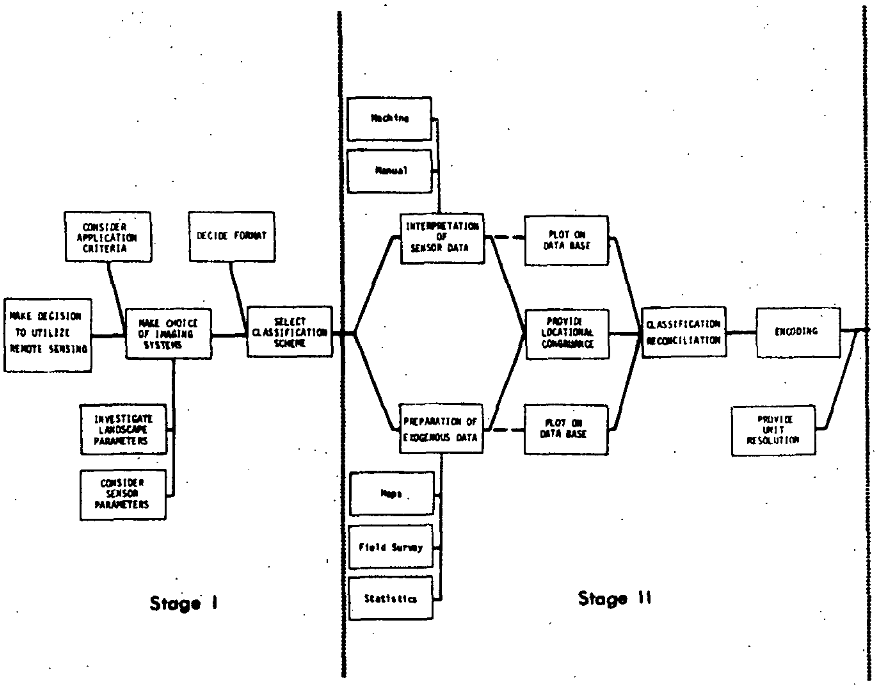


Figure 7.2a. Stages I and II of the Information System Scheme

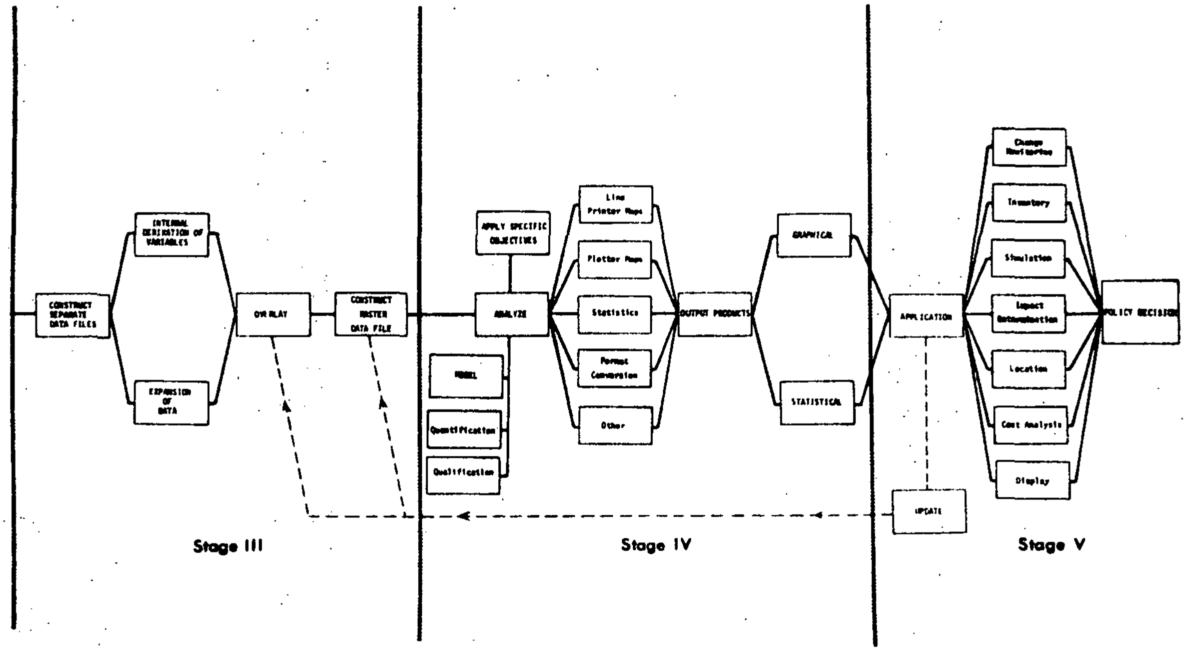


Figure 7.2b. Stages III, IV, and V of the Information System Scheme

onto an image overlay will necessarily capture any inherent geometric image distortions. The use of algorithms will provide for location congruence with the data base. Another alternative would be to interpret the data directly from a hand rectified grid overlay which is locationally congruent with the data base. These methods were, in fact, developed during earlier research.

Stage III - Data Base Files

In Stage II separate data files are created for each environmental phenomenon which is discretely classified and interpreted from various data sources. Furthermore, all of these data are rendered locationally congruent. In Stage III the Data Base Files are subjected to various manipulations which internally produce additional data. By deriving variables, correlating existing data, and applying various data overlays, the land resource analyst makes available a large number of important applicators.

In many cases, additional discrete environmental variables can be calculated. These would be time consuming to derive manually, but are, nevertheless, very important for applications to resource management. The derivation of these variables may be approached in two ways. The first includes programs specifically designed for a particular application. Data inputs may be either: (1) a single variable from the data file with calculations afforded by spatial arrangement, or (2) inputs in the form of a special model utilizing empirical data not spatially correlated.

Consideration has been given to two dimensional data where the x and y coordinates specify location and the z axis provides the

phenomenon (event). There are cases, however, where more than one event would need to be plotted with respect to one variable. For example, air pollution would have the properties of being physically three dimensional requiring the event (e.g., oxidant concentration) to be recorded along a fourth axis. Again, this is where computer capabilities become attractive. The use of more than three axes can enable the use of data with three physical dimensions plus whatever phenomenon exists at a physical point in space.

Overlay processes combining a series of single-variable matrices with spatial location held constant have been utilized extensively. Ian McHarg's method of regional landscape analysis is a well known example. McHarg's method involves the plotting of variables on acetate rather than overlaying them physically to visualize the spatial correlations and juxtapositions. Obviously the more variables that are added, the more confusing the display becomes and eventually any empirical applications become difficult. The overlay process, as used in the present system, is accomplished internally within the computer. Thus, an indefinite number of phenomena can be overlaid, enabling both easy retrieval, manipulation, quantification, and modeling.

Stage IV - Analysis and Products

The next stage of the system deals with data analysis, data modeling, generation of desired products. It is useful to remember that the integration and application of remote sensing techniques to land resource management programs is not just a problem of acquiring and interpreting remotely sensed imagery. One must also analyze the data for the purpose of providing information to land resource management programs and objectives.

Analysis of spatial comparisons provided by the integrated master data file is accomplished by selective retrieval of variables as required by specific application objectives. Each category within each variable is weighed by assigning relative values corresponding to relative desirability (positive or negative) with respect to collected environmental phenomena. The model output is generally not another variable (although it could conceivably be used as such), but rather is in the form of a series of relative assessment values. In a corridor location model, for example, soil types, geology, slopes, sun angles, and other applicable environmental phenomena, are assigned determined values in order to obtain a quantitative assessment of suitable corridor location for a particular use (i.e., highways, power-lines, etc.).

Stage V - Applications

The utilization of the described concepts affords the application of environmental data directly toward the land resource decision process, for integrating synoptic data. User options include integrating additional overlays enabling synoptic analysis, or simply updating the master data file by obliterating obsolete data. Options for applicationsto management and policy decisions are governed by various goals of both data synthesis and data presentation.

A brief description of some possible applications to the land resource planning and management process follows:

1. Monitoring. This concept applies to the detection of synoptic phenomena, such as rural-urban fringe analysis, urban blight,

crop morphology throughout growing seasons, levels of various environmental pollution, etc.

2. Inventory. When planning for regional growth and development, for example, resource data are often insufficient or relatively non-existent. Remote sensing techniques provide efficient and expeditious surveys, and minimize problems of inaccessibility over large areas of difficult terrain or cover. Imagery provides vast amounts of environmental data to be recorded and interpreted, and data files allow for the storage, retrieval, and presentation of vast amounts of data useful to the resource analyst and planner.

3. Simulation. Often resource planners attempt to simulate political or economic outcomes, such as land use changes, before making various recommendations or decisions. The construction of graphical displays allows the presentation of relevant information to the participants in the "gaming" process.

4. Impact. Planners often must ask themselves "What if we do . . . and what if we don't . . . ?" With the concepts and systems described, assessments of relative "impact" may be generated to enable planners, first, to better answer such questions, and second, to provide alternative comparisons.

5. Location. Once the decision is made regarding, for example, the development of a certain activity, the question becomes one of optimum location. Quantitative assessment of environmental, political and economic parameters may be used to narrow the choice to several alternate locations.

6. <u>Cost</u>. When economic inputs must be considered, assessments of cost and cost alternatives may be easily computed using the proposed system.

7. <u>Displays</u>. Communications between planners and policy makers is often inhibited due to the use of information formats that are difficult to interpret. Flexibility of display modes allowed by this system should ease communications.

Historically and presently, inventory, planning, and management of land resources is an extremely variable process among regional population concentrations and frequently non-existent or minimal in smaller populations. Land use maps, for example, are costly to produce due to dependence on traditional ground survey methods, and once completed, are of limited historical value. The value of current and dynamic regional land use data and maps is their potential for "synoptic use in observing economic patterns (and resources) rearranging themselves".

There is growing agreement that the "state-of-the-art" of remote sensing has advanced to the point of being very useful for the detection of environmental resource data. The need for more, better, and timely land use data for planning is obvious. Also present is the need to evaluate and manage our resources. Various remote sensing techniques are more applicable than any other method of surveying numerous environmental phenomena as necessary to facilitate the making of resource management decisions. The realizations of automated systems to integrate data derived through remote sensing techniques with multiple sources of exogenous data, and the ability to manipulate,

store, retrieve, display, and update the resulting information, will enable the transfer of remote sensing applications and technology into the effective operations of resource management.

7.2.1.2 Computer Prepared Thematic Mapping

Mapping requirements of the Earth Resources Technology Satellite experiments are already placing a great burden on many cartographic services. Costs and time involved in preparation of initial base maps of southern California test site areas and experimental updating of thematic changes detected from current underflight imagery force the utilization of an automatic thematic mapping system. Several systems for computer mapping are available to the Riverside campus and are an integral part of our information system. While the following discussion will deal primarily with a cartographic line type thematic map program (CALFORM) there is a close relationship among our various computer mapping systems.

The GRID mapping system discussed in the previous section and the Polygon Information Overlay System (PIØS) will be utilized in conjunction with CALFORM to develop a computer based Geographic Information System. Each of the three systems has its good attirbutes and each has its shortcomings. The PIØS system is an efficient method for converting image data into digitized form for computer manipulation. The grid system with its equal area cells is essential when correlating spatial data from several sources. Thematic maps prepared by CALFORM best simulate cartographic maps that we are accustomed to viewing and in many instances are the most perceptually acceptable. Current investigations at Riverside intend to utilize the polygon input system and

then convert the data to equal area grid cells within the computer itself. This procedure will eliminate a great deal of slow tedious manual coding required to produce the GRID maps for multi-source correlations such as the data discussed in the previous section.

The development of a computer based information system for correlation of multi-source data will increase the need for thematic maps. The GRID mapping program produces thematic maps on the line printer simulating various legends by various density levels produced by overprinting of type symbols. The CALFORM mapping system is much less flexible than the GRID system, but it produces a much clearer line drawing looking much like a map drawn by a human cartographer.

CALFORM computer input differs greatly from the GRID system which limits its flexibility within the computer, but enables very rapid updating of information once the base map has been prepared. The CALFORM program records the x-y coordinate of each vertex of every polygon (regardless of shape or size) and, in addition, it numbers each polygon. Once recorded, the only requirement for reproducing an individual area or cell is to instruct the computer as to the cell number desired and respective legend code. The legend can be changed for any cell on each subsequent computer run. As an example Figures 7.4a, b, and c are computer prepared maps of the Perris Valley study area, and are discussed in another section. Six hundred thirty-six cells or polygons were identified with the 44,928 acre area. One thousand three hundred sixty-seven vertices were identified and their x-y coordinates were read into the computer

PIØS PLOT OF MAP NO. 119

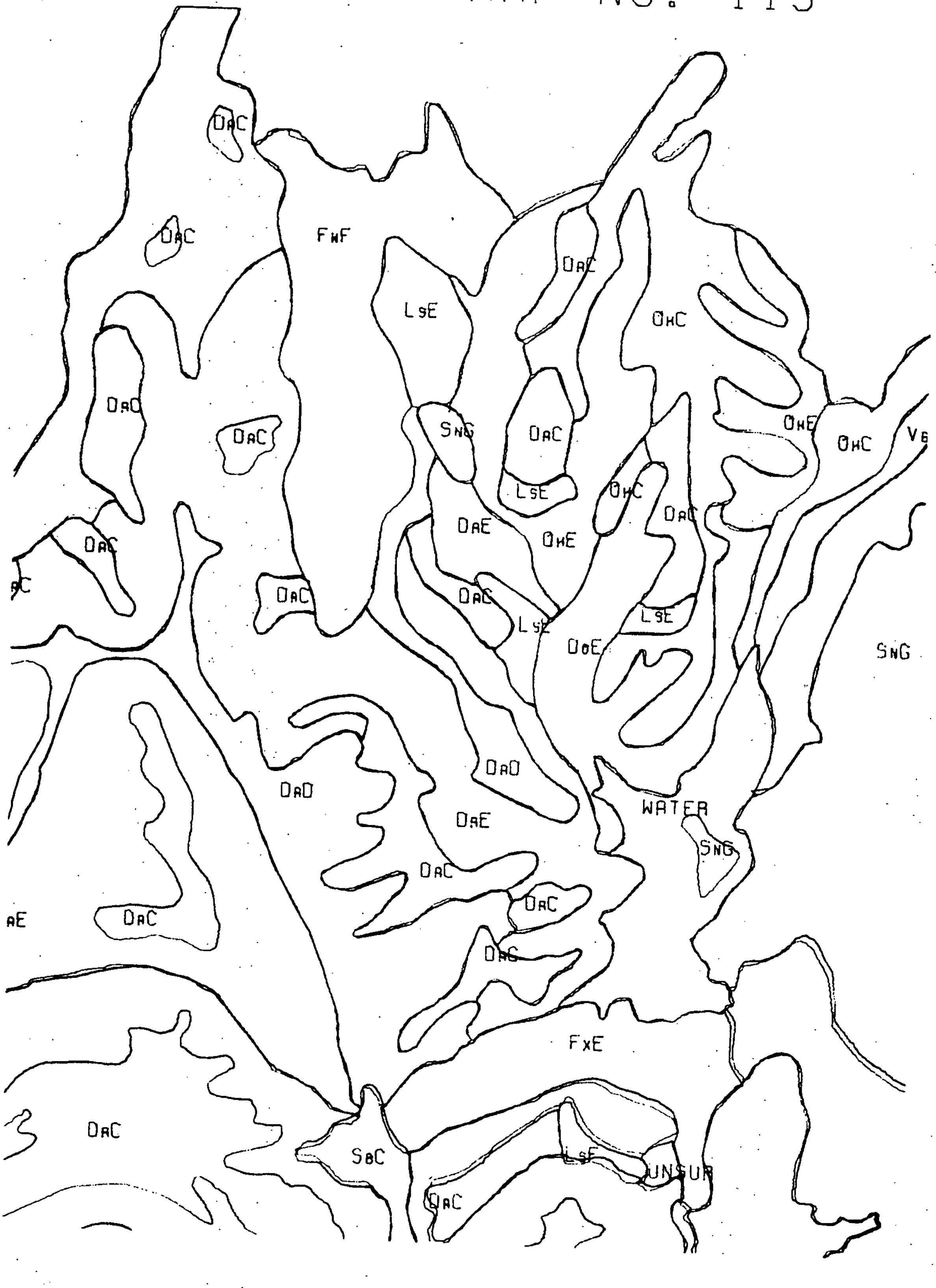


Figure 7.3. PIØS soils map of part of San Diego County.

to a tolerance of one-thousandth of an inch (0.001") by means of a coordinate digitizer. Obviously, the vertices serve more than one polygon most of the time.

It has been found that the digitizing process proceeds more rapidly if an outline of the thematic boundaries is first drawn onto an overlay of the image or associated base map. Once the overlay has been prepared, about four hours are required to digitize an average land use map which is the size of a 7.5 minute topographic sheet. However, a vegetation or soils map of the same size may require up to 40 hours. The great advantage of the CALFORM map is the short time it takes to update the data. Figure 7.4a depicts a portion of the Perris Valley area interpreted from March 31, 1971 imagery (NASA Mission 164). Figure 4b illustrates the land use interpreted from U-2 imagery of December 9, 1971. The latter interpretation took about 30 minutes and the change in the previously prepared computer map took only 30 minutes. The excellent resolution on the U-2 imagery facilitated the rapid interpretation.

Another attribute of the CALFORM thematic map system is the ability to quickly produce a new map to show a single category of data or information. Figure 4c is an example of a single category map showing the changes that took place between the two time periods of the previous two maps. Any one category or combination of categories can be produced with less than an hour's preparation time once an initial CALFORM map has been prepared.

The Perris Valley computer maps showing updated information demonstrate the need for modification of the CALFORM program to provide

acreage calculations. Ability to calculate acreages quickly will enable investigators to prepare tables reflecting various land use changes (Table 7.4). Within the Perris Valley area, a most important seasonal variable is the consumption of water by agricultural activities. The table indicates that 3410 acres of field crops which normally utilize irrigation water were permitted to lie fallow on December 9, 1971. An additional 7310 acres of field crops that are usually dry farmed were also out of production. The timely reporting of such data can prove invaluable to water resources agencies.

Preparation of computerized base maps for the test site areas in southern California utilizing the CALFORM system is proceeding. These additional maps are being used in testing the ability of ERTS-1 imagery to provide evidence of change in the environment.

7.2.1.3 Rural Land Use Inventory and Change: Perris Valley

A primary investigation of the Riverside researchers during the past 24 months has been that of preparing a data base for analyzing the impact of the California State Water Project, and its terminal reservoir, Lake Perris, on the land use and development of the surrounding Perris Valley. Researchers are investigating the effects and implications of water transfer on domestic, industrial, agricultural, and recreational land uses and regional development, as observed and recorded by high altitude aircraft and spacecraft remote sensing devices. These studies initially followed a rather intensive analysis of a small study area, and considered several social and economic

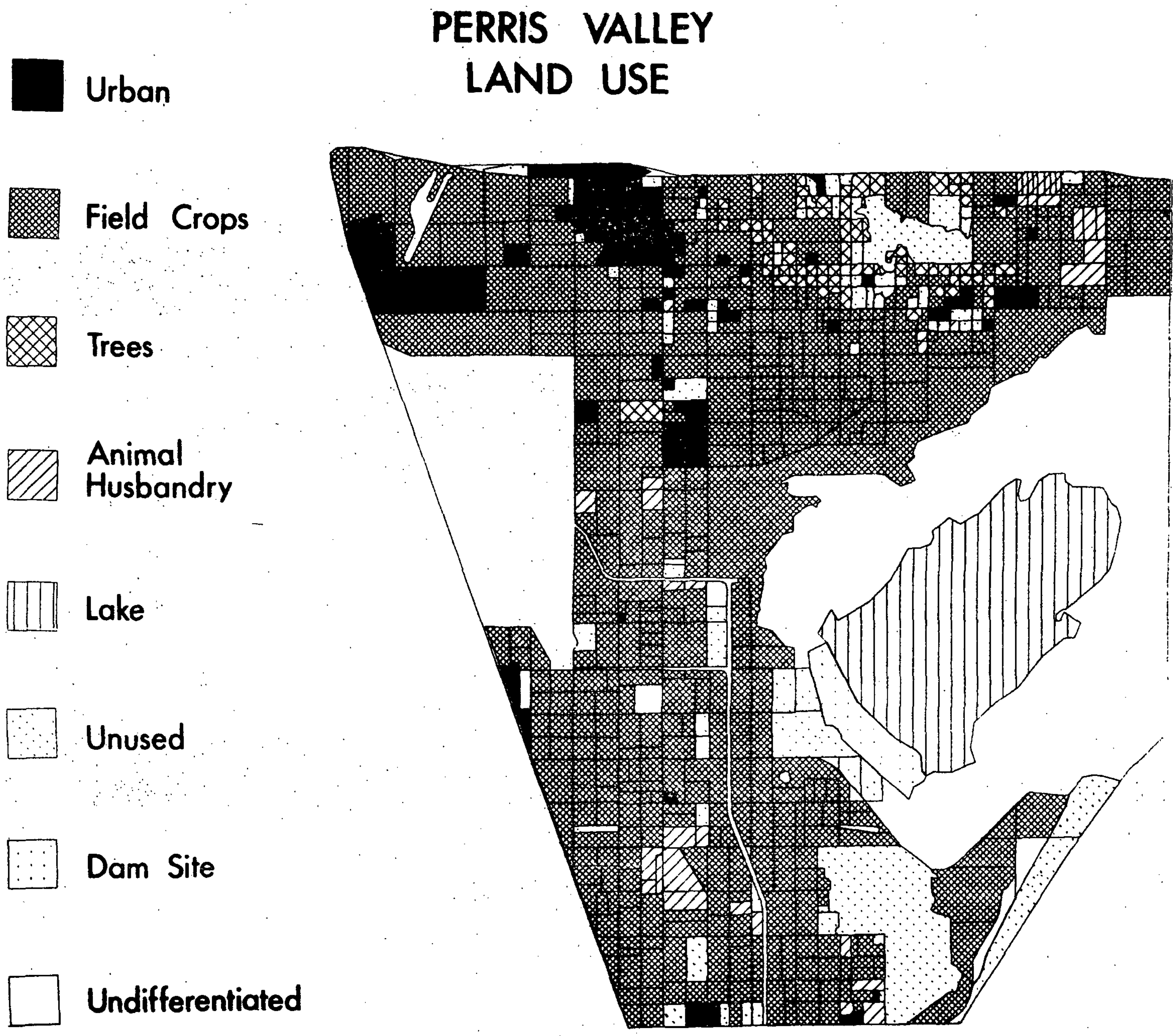


Figure 7.4a. CALFORM map showing land use in a portion of Perris Valley, based on NASA photography obtained . March 31, 1971

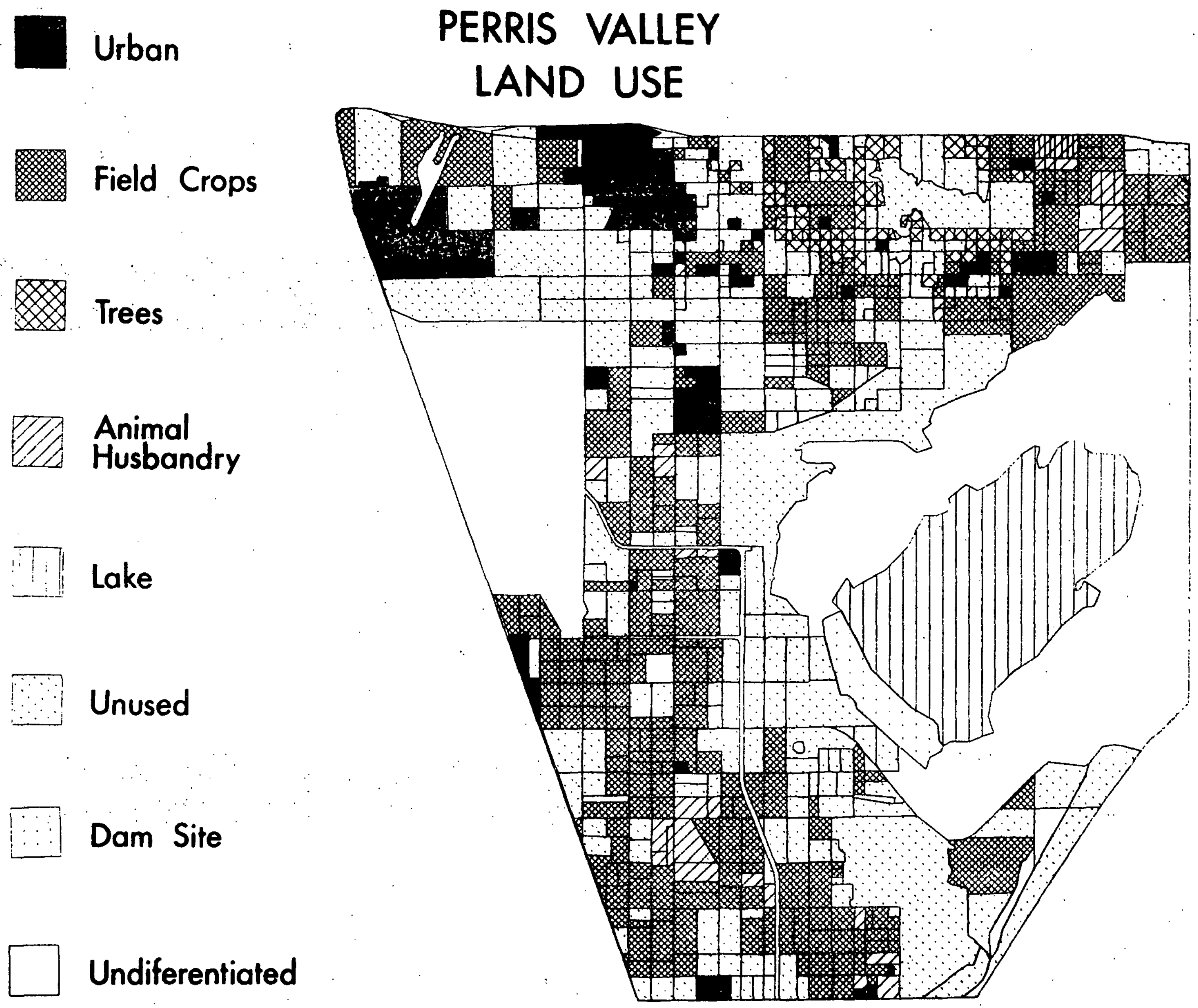


Figure 7.4b. CALFORM map showing land use in a portion of Perris Valley based on NASA photography obtained on December 9, 1971.

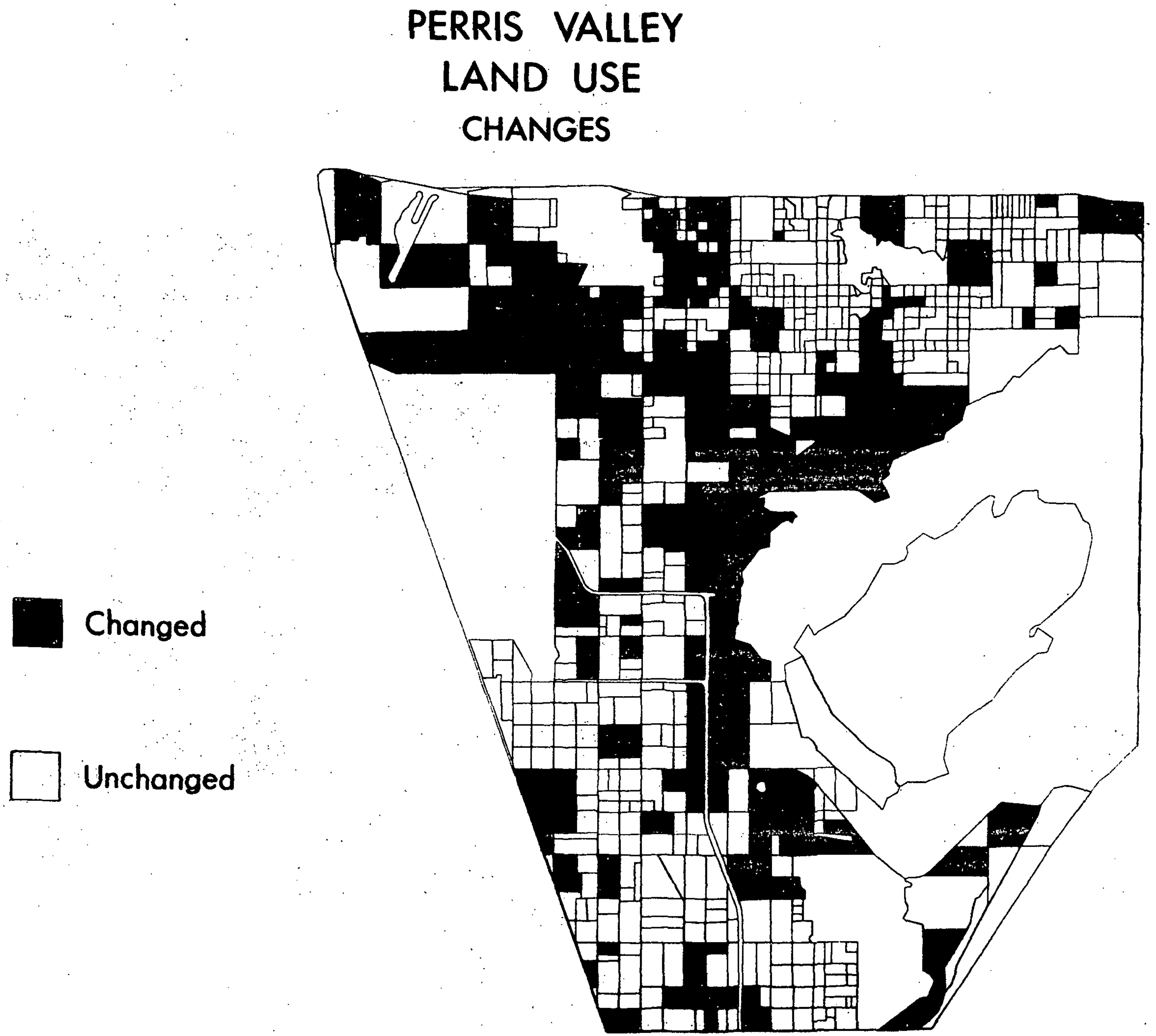


Figure 7.4c. CALFORM single purpose thematic map showing changes in land use which occurred during the period spanned by Figures 4a and 4b.

TABLE 7.4. PERRIS VALLEY LAND USE SUMMARY OF ACREAGE AND CHANGE
(ALL UNITS IN ACRES)

CLASSIFICATION	March 31, 1971			CHANGES		December 9, 1971		
AGRICULTURAL AREAS	DRY	IRRIGATED	TOTAL	DRY	IRRIGATED	DRY	IRRIGATED	TOTAL
FIELD CROPS	13,590	6,110	19,700	-7,310	-3,410	6,280	2,700	8,980
TREE CROPS		900	900				900	900
ANIMAL HUSBANDRY (Poultry, Horses, Cattle, Sheep)			900					900
UNUSED (Vacant, fallow)	3,540		3,540	+7,310	+3,410	14,260		14,260
UNDIFFERENTIATED			370					370
TOTAL AGRICULTURAL	17,130	7,010	25,410			20,540	3,600	25,410
NON-AGRICULTURAL AREAS								
URBAN AREAS			2,040					2,040
DAM SITE			510					510
FUTURE LAKE SITE			4,300					4,300
LAKE HILLS & RECREATION			5,700					5,700
MARCH AIR FORCE BASE			3,100					3,100
OFFSITE IMPROVEMENTS (Roads, Ditches, Flood Control, etc.)			3,868					3,868
TOTAL NON-AGRICULTURAL			19,518					19,518
TOTAL ACREAGE			44,928					44,928

factors which can influence regional land use and development. Results of these studies have been reported previously and are only summarized in the following discussion. Recent approaches have been designed to expand the area of study, and subsequently to generalize and reduce the detail and resolution of data recorded and analyzed. Thus, an approach to a local environment is evolving into one of a regional environment, yielding a technique that is more applicable to the areal analysis of spacecraft and simulated spacecraft type data.

Previously reported studies included: (1) a land use survey of a sample study area using both ground observations and the interpretation of high altitude color infrared metric photography; (2) a survey of residential attitudes towards the development of Lake Perris and the Perris Valley, and activities by local developers and planners in the area; and (3) a preliminary study of methods for estimating potential population, development and expansion, and/or land value increases in the Perris Valley using conductive sheet analog models.

During 1971, seasonal or short term agricultural land use change was monitored for the Perris Valley test site. The maps used to illustrate computer mapping techniques were constructed to monitor these changes in Perris Valley. As an overview, such short term changes and present studies have focused upon the decision to intensify land use. Preliminary results of this investigation indicate that in several areas two types of land use are replacing agriculture.

In the northern part of the plan around March Air Force Base and along the transportation artery provided by State Highway 60, residential subdivisions, (both single and multiple family dwellings) are being

constructed on land previously dedicated to agriculture. This is not a new trend and does not owe its existence to the inception of the California State Water Project, although information concerning Lake Perris and surrounding state recreation facilities have had some effect as a stimulus to growth.

Throughout the Perris Block of the Peninsular Ranges (roughly the area between the Santa Ana and San Jacinto Mountain Ranges from Riverside to Rancho California) recreational oriented land uses have replaced agriculture at a limited number of sites. Most of these are, according to Clawson and Kenetsh (Economics of Outdoor Recreation, 1967), intermediate facilities which are neither population nor resource oriented. Although some of these sites are designed as centers of second or recreational residences (a typical occurrence in the northern Coachella Valley) most often the developments serve as recreation vehicle campgrounds, mobile home sites, or as centers for day uses. There is no doubt that proposed recreational developments associated with the California Water Project are partially responsible for the development of these uses. Hopefully research during the next years will provide more conclusive results concerning these already identified trends.

7.2.1.4 <u>Monitoring Rural-Urban Transitions</u>

<u>Introduction</u>

A preliminary investigation of one Riverside researcher, now completed, concerns the use of synoptic remotely sensed imagery for monitoring regional change (i.e., involving rural patterns) in which

urban land use successions can be predicted ahead of their actual development. This is a study in urban dynamics that has both practical and theoretical values. Urban and regional planners, thus, can foresee transition problems and monitor them as they develop. Students of urban morphology can observe the processes of rural to urban transition and land use succession.

Background and Procedure

The study began two years ago with a slightly different objective. Snyoptic imagery was to be used in examining freeway impacts on agricultural land use, the expectation being that agricultural uses would change as anticipation of the freeway rose, as the actual construction proceeded, and as the route finally was completed. It was expected that labor and capital inputs to land would be intensified to raise productivity in keeping with higher carrying costs for rural land now taxed at urban rates. Instead, the phenomenon of factor disinvestment, or the minimization of factors inputs to land was observed. Sinclair described this phenomenon in a recent journal article, "Von Thünen and Urban Sprawl," (Annals of the Association of American Geographers, Vol. 57, 1967), but he did not test it empirically, nor did the few other investigators who observed it analyze its causes. Examples of disinvestment patterns and their origins are yet unclear. Rather than a progressively more intensive production-factor-use-agricultural approaching an urban fringe in accord with the 150 year-old Von Thünen theory (which suggests than land rent appreciates from locational utility, and that land uses are ordered by their ability to pay these rents and the transportation costs), the proximity clouds the long-run planning horizon

and forces fringe land owners to adopt short-run plans. This is particularly true in dynamic situations, e.g., when a major transportational route is constructed. Production factor use is minimized because labor earns higher returns in the city; capital has higher returns in land speculation or in investments other than farming. Land, as a consequence, is farmed without much capital or labor input, and such extensive uses as grazing, and the farming of barley and other field crops prevail in areas "clouded" by urban proximity.

Results

The study area is a five-sided figure, topographically defined by the highest summits of two hill masses which enclosed the relatively narrow Walnut Valley. Parts of three and all of a fourth incorporated city lie in the study area but most is still unincorporated. The orientation of the study area follows the route of the freeway; as such, its dimensions are approximately eleven miles east-west by seven miles north-south. It includes 37,023 acres (14,989 hectares) of mixed land uses, with agriculture and vacant land predominating.

Urban land uses succeeded agriculture on 4,719 acres (1,910 hectares) of agricultural land, and only 1,076 acres (467 hectares) of vacant land were absorbed by urbanization. With that in mind, nearly twice as much urban land use and population can be sustained by absorbing the remaining agricultural land, thereby raising the holding population of the region (Statistical Area 26.0, Los Angeles County Regional Planning Commission) to approximately three times its present figure (179,000).

Land use changed within agriculture in a number of ways before urban land use (residential, industrial, institutional, etc.) succeeded. Five types of decisions made by land owners were identified as:

1. Intensification: the increase in factor use as in the replanting of citrus, the enlargement of a dairy, or the planting of row crops in place of field crops.

2. Direct conversion: the change of productive agriculture to urban use, as in the replacement of productive citrus groves by subdivision.

3. Succession: the following of low-productivity agriculture by urban use, as urban barley fields or deteriorated citrus orchards are followed by a subdivision.

4. Disinvestment in Lieu: the following of productive agriculture by a less productive agriculture, as when citrus is replaced by barley farming.

5. Disinvestment: the allowing of agricultural uses to deteriorate *in situ*.

Land owners adopted these strategies in different proportions depending on the urgency with which they perceived conditions for land use change. Population growth was continuous in southern California through the first decade of this study period and slowed only recently. Walnut Valley growth, however, was an exception to this general case since growth was great. Freeway announcement, construction, and completion stages are fairly well defined in the rate of housing constructed as in land owner decision-making processes. Owners tended to adopt land sale enhancement strategies (disinvestment in lieu) in periods of "booming" growth and disinvestment strategies when sales (lending

rates, financing availability, etc.) were off. The intensification of agricultural land use was a much less important decision than expected. In broad terms, the expanding Los Angeles fringe through Walnut Valley triggered land use change to urban uses and agricultural decline through disinvestment stages. Urban land use succeeded when land was "properly prepared," i.e., already cleared of arboreal crops to minimize land development costs, or where terrain was easy to develop. Some land holders found buyers and sold acreage with producing crops despite agricultural opportunity costs, and converted to urban uses by the direct conversion method.

Research concerning the preparation and transformation of rural land to urban uses is continuing at the Riverside campus. Theoretical statements are, at best, hypothetical on the basis of even intimate observations at a sample location. In order to substantiate previous statements, the hypothesis of disintensificiation of agricultural land use immediately prior to urbanization will be tested in four other areas. Tentatively these areas are: (1) The Dairy Valley area of Cypress in Los Angeles County; (2) The Placentia area of Orange County; (3) an area of the East San Gabriel Valley in Los Angeles County; and, (4) either the Dominguez Hills or Venice area of Los Angeles County.

Each of the above locations exhibits different agricultural land uses. Hopefully this additional research will not only lend credence to the hypothesis under consideration, but will also establish what other types of agricultural land uses undergo factor input reduction before giving way to urbanization.

During the past year, research has concentrated on typical agricultural forms of southern California which, in comparison with farming nationwide, tend to be highly capitalized, intensive and specialized. In the citrus industry emphasis is placed on the manner in which each form evolves under urban pressure, particularly on remotely sensed evidence of change that can be supported by ground truth data (e.g., production data, both inputs and outputs). A portion of Orange County, California, served as a test site (Site 2 above). This region, bounded by the Santa Ana River on the south, the Orange Freeway on the east, and the Puente Hills on the east and north, contains two incorporated communities, Placentia and Yorba Linda, and substantial evidence of urban encroachment into agriculture. Other reasons were important in the site selection: (1) the off-center location of the region and its delayed urbanization (ample photo coverage was better assured); (2) the excellence of soil with the result that citrus production tends not only to deter urbanization but make its impact more dramatic; and (3) the abundance of related "ground truth" data.

Urbanization began rapidly in the region after 1960, prompted by local capital projects, and has fluctuated with the vagaries of the building industry. Idled land and urban land uses had almost totally replaced the citrus landscape by 1972. The decline of citrus cannot be attributed solely to urbanization, however, and the research was extended to provide the explanatory factors necessary to provide a complete setting for citrus disinvestment. Economic health was

generally poor in the industry for some time. Urbanization became only a fortuitous occurrence that enabled individual growers to recover past losses in large-scale land appreciation that followed growth of southern California's population. Urban impacts were felt in many sectors: (1) costs of production rose; and (2) difficulties of production rose (infrastructure breaking down). As a result, growers became sorted in terms of their propensity to withstand these impacts and their outlooks changed. Higbee (1969) classified on an urban fringe in four categories: (1) part-time farmers; (2) under-capitalized farmers; (3) serious farmers; and (4) investor farmers. All were represented in citrus districts, historically and presently, with only their relative numbers changing. Part-time farming was the original basis under which the industry spread on small farms. Labor efficiency and economies of scale were difficult to achieve at the early stage of the industry, but labor was disinclined to shift to other activities. (Eventually, growers took on other employment as opportunities were presented.) Marginality resulted from lack of a sound knowledge concerning the raising of sub-tropical fruits and a difficulty in optimizing physical constraints (soil, exposure, micro-climate). "Boom" years attracted producers whose numbers were adjusted by recurring periods of "bust." Citrus acreage and farm numbers, however, represented heavy fixed investments which caused contraction of the industry to come slowly. Serious growers deserve special attention in subsequent paragraphs. Investor farmers, aside from modern "corporate" and "tax-shelter" farms, were important

in a transition period when groves were purchased, farmed, and operated by managers and phased in keeping with an overall development scheme.

By monitoring the fringe, one observes various planning strategies. Some of these can be identified with a specific type of grower. These decision patterns can be divided into three types: (1) groves with good care; (2) groves with minimum care; and (3) abandoned groves.

Every grower bases decisions on grove potential. This includes soil, production costs, and management ability factors, and their availability, or, in other words, physical, economic, and social considerations. The actual production process finds these factors increasingly more mobile with their scarcity, i.e., management labor is a more mobile input of greater scarcity than an opportune economic situation, etc.

Soil had much to do with a grove's initial prospects. A poor grove was worth its cost until recently; a good grove was dear at any price at any time. Coupled with efficient and competent management, sites with good soil produced incomes which could offset rising production costs for considerable time. As the citrus landscape evolved, growers on poor soils who always had poor production and were most marginal tended to leave the industry first. The actual decision depended much on existing conditions, e.g., the availability of alternative uses for the land, and the change in any of the "urban" pressure factors: rising taxes, water, and labor costs, and problems associated with people that make farming difficult (pilferage, vandalism, complaints, air pollution). Depending on the extent of this assemblage of influences, a grower either

abandoned the grove (ceased irrigation) or adopted a minimum care program (cut back on spraying, replacement, trimming). The choice among decisions can best be explained by examining the reasons for maintaining good cultural care.

Good groves, while they become increasingly uneconomic through time, were maintained so that output could offset fixed costs of production (taxes, depreciation) and perhaps pay a profit in occasional good years. The following table illustrates why.

TABLE 7.5. TWENTY-YEAR COMPARISON OF PRODUCTION COST (PER ACRE)

Yield	500 boxes			400 boxes	
Price	$2.00/box			$1.25/box	
Income			$1,000.00		$500.00
Costs					
Taxes		$60.00		$500.00	
Water		15.00		75.00	
Grove care*		60.00		140.00	
Pest control		60.00		100.00	
Miscellenaous		15.00		30.00	
Total			$ 210.00		$845.00
Net Profit			$ 790.00		-$345.00

* Includes irrigation labor, weed control, rodent control, extra care for replants, management.

Source: George Jacobsen, Placentia, California, grove manager.

Yields declined over the past twenty years due to tree aging and air pollution. Prices declined due largely to overproduction. Production costs, on the other hand, rose considerably, particularly costs associated with urbanization (taxes, up 833%; water costs up 600%; labor costs, up 300% (estimated)). By producing, a grower reduced the potential loss he might incur. For example, taxes he could not escape whether or not he continued raising oranges. Provided the grove is sound, an additional \$345.00 investment in cultural care provides \$500.00 in income. While he does not make money on the crop, he reduces his potential loss by \$155.00 by gambling \$345.00. Alternatives are less attractive: razing the orchard and planting a more remunerative crop for interim use costs \$600-700 per acre for tree clearance and up to \$2,500 per acre improvements costs for specialized crops, such as strawberries, which could return a profit. Such alternatives were feasible provided the soil was suitable, skills were present, and the farmers were so motivated. In general, the industrial zoning of groves on sandy soils of the Santa Ana River floodplain (eminently suited for strawberries) were unlikely to become urbanized within a short time and lent themselves to this alternative. Over most of the region, however, it was not practical.

Minimum care could be practiced by reducing cultural care expenses dollar for dollar with reduced income. If loss in income exceeded savings from reduced production costs, it would not pay the grower to adopt minimum care; if loss in income was less than the savings, minimum care provided a viable alternative investment strategy. What few growers

knew at the outset was that minimum care had a cumulative effect: while quantity and quality of output did not decline appreciably in the first year, subsequent crops were increasingly poorer. If grove quality was insufficient to produce crops equal in value to production costs (the variable portion) <u>minus</u> taxes (a fixed cost), a grower would likely abandon production.

The 1972 citrus landscape illustrates all three strategies. In general, they are associated with types of farmer according to Higbee (1967), and they also correspond with decision types distinguished earlier (Goehring, 1971).

TABLE 7.6. DECISION TYPES/STRATEGIES

Farmer Types	Farmer Strategies	
(Higbee, 1967)	(Placentia-Yorba Linda, 1972)	(Goehring, 1971)
1. Part-time farmers	1. Minimum care until eventual abandonment	1. Disinvestment followed by a succession of urban use
2. Under-capitalized farmers	2. Abandonment	2. Disinvestment followed by a succession of urban use
3. Serious farmers	3. Good care until the grove is sold; possible conversion to higher paying crop	3. Direct conversion to urban use; intensification within agriculture
4. Investor farmers	4. Minimum care; often abandonment; possible clearing with/without replanting a higher yielding crop	4. Disinvestment; disinvestment in lieu; possible intensification

The emphasis on good management and efficient production on good soils has led to grove management as a field of labor specialization. This

type of "serious farmer" can often be associated with investment situations, e.g., future school sites, power line rights-of-way, mineral reserves. Leases for long terms (20 years or more) with some assurance of permanency and lower tax rates permit continued production by managers operating as individual farmers. Here, it is the public (school sites), the utility company, or the mining industry who has invested and obtains interim income from lands planned for other uses. Grove care practices are good with considerable consistency irrespective of disinvestment or abandonment surrounding these institutional "islands."

Periodic air photo coverage permits monitoring changing conditions within the grove that are paralleled by investment strategies employed by grove owners. As such, periodic observations of grove condition lead to rapid identification of parcels likely to become urban and the time in which they might be converted. Having such information is an obvious benefit to planners concerned with the evolving urban landscape. It may be possible to establish similar indicators for inner-urban space as well. Most urban planning is done with data derived from varied sources, largely secondary in nature, due to the absence of a data source specifically oriented to planning. Most secondary data are out-of-date once in the hands of the user-planner and the quality of decision making derived from these data thus becomes deteriorated. Planning in light of environmental considerations, an approach currently ascending in importance, requires identification of qualitative parameters in ways that can be quantified. Remote sensing tools provide ways of obtaining consensuses on quality (e.g., grove condition) and monitoring the way in which quality changes over time by the synoptic facility of inexpensive aerial

photography. If planners would incorporate such data in a manner that identifies the processes behind each change in the landscape, their decisions not only would be improved but their abilities to model the interrelationships within the physical-economic-social environment would be substantially increased to the benefit of projections and policy recommendations for the future. Planning has tools to improve the quality of life in the future, but their effectiveness is reduced by lacking an understanding of how tools should be applied. Research tools, such as remote sensing, offer better information for determining processes that lead to understandings that make projections more valid and policy recommendations more pertinent and inevitably effective.

7.2.1.5 Urban Regional Land Use (Atlas)

The metropolitan area of which Riverside and San Bernardino form the core, has been selected by USGS as one of 27 sites for study of urban land use analysis and change in the Urban Atlas Project. The basic data gathering system of mapping land use information on USGS 1:24,000 sheets is being continued until its completion in the near future. Computer maps are also being prepared. Five quadrangles have been finished and are mosaicked together.

This large scale data base, while useful in its present condition, also allows rapid and useful correlation with ERTS-1 and ERTS-B imagery. The sequential nature of ERTS-1 imagery fits in well with the requirements of the project, those of monitoring urban and regional land use changes. The conversion of conventionally mapped data into a format

for computer storage and manipulation allows quick comparisons of several dates, and thus rapid assessment and calculation of urban changes.

Present plans also include the production of a technical report summarizing all the work of the project at UCR. It would include details on the methodology and techniques as well as data from selected sites in the study area. This report would provide local county and city planners with quantitative data and adaptable techniques for their use in evaluating land use changes and processes occurring in the area. It also would reflect the ability and intention of this research program to go beyond the limited objectives stipulated by USGS and make information available for practical, local agency utilization.

7.2.1.6 Mapping Montane Vegetation

A previous NASA-funded study produced a discussion concerning the application of mapping montane vegetation in southern California (Minnich, Bowden, Pease, 1969). The study included several vegetation maps of the San Bernardino Mountains in areas where color infrared aerial photography had been acquired from NASA and other sources. The original photo-interpretations were made by Richard A. Minnich. Subsequent to NASA Mission 164, Minnich re-examined the earlier effort, evaluated the more complete photographic coverage of Mission 164, and made certain revisions to the vegetation map. An addendum to the earlier study provides a number of technical revisions as well as extension of the area mapped. No effort is made here to reproduce the revised map.

Figure 7.5. (See fold-out page which follows.) Land use map of Riverside-San Bernardino Area based on the interpretation of NASA-acquired color infrared aerial photography.

Riverside—San Bernardino Land Use Map

The addendum which was reproduced in the 1971 annual report has been expanded this year under NASA support into a detailed methodology for vegetative mapping using remotely sensed imagery. The entire system is too lengthy to reproduce as part of this report; however, the following synopsis with examples should illustrate the utility and potential accuracy of this methodology. The area where the methodology was developed is limited to southern California, but application potential of this technique can extend to any brush or tree covered area for which there is high altitude imagery.

The use of color infrared imagery in the analysis of vegetation has been primarily a testing procedure. The sensor and sensing techniques have been examined or, alternatively, the contribution of CIR as an aid in traditional vegetational analysis has been explored.

In the study of the San Bernardino Mountains, the most effective use of CIR was found to be as a basic data source. Whereas previously, (either due to limited coverage of aerial imagery or due to underlying theoretical constraints) CIR was only an accessory to montane vegetation mapping, this study utilized the photography as others use a field survey. The field survey yields information, data from which constitutes the vegetation analyst's basis for classification. In this mapping methodology only data which could be extracted from the imagery was considered significant to the development of the classification.

Recently a 7.5-minute quadrangle has been mapped in greater detail than previously. This mapping has extended and has led to a revision of Mr. Munich's classification. The following tables demonstrate the formulation of the classification and the important parameters by which

each class may be identified. Texture, physiognomy, seasonal variation, and traditional photo-interpretive clues have been cited, as well as the false color signatures of CIR. It is these characteristics, in concert, found throughout the study area, which yield consistent data for the classification.

The "Family Tree" illustrates how the classification grows either from single species identification or from multiple species identification. For example, the unit of coastal sage has a distinctive signature. The various species within the unit are not separable in the aerial photography. The distribution of the unit is of sufficient size at the scale of mapping to warrant a class. Similarly, the three species Ceanothus crassifolius, Rhus laurina and Rhus ovata may be identified in association but not as separate species. These species are found in the study area only with Adenostoma fasciculatum. This combination is mapped as c_s. Adenostoma fasiculatum is found in association with the three species mentioned above, but its signature is unique in this environment. Where Adenostoma fasciculatum is found without associates, it can be mapped Caf. These concepts are summarized in Table 7.7.

TABLE 7.7. "FAMILY TREE" (VEGETATION CLASSIFICATION ILLUSTRATION)

Communities by Munz (1965)	Species Identified		Associations
COASTAL SAGE	Artemesia Californica Encelia farinosa	CS	COASTAL SAGE
	Adenostoma fasciculatum	Caf	CHAMISE CHAPARRAL
	Ceanothus crassifolius Rhus laurina Rhus ovata		C_S--SOFT CHAPARRAL

As overlapping distributions become more complex, the "tree" becomes multi-branched, but the principle remains the same. Single species identification is mapped if the areal extent is significant. Multiple species are mapped if the same conditions exist. Multiple and single species may be combined to form separate and distinct classes with unique distributional characteristics.

Accuracy in vegetation identification from aerial photographic transparencies is fundamentally dependent on whether the photographic scale and spatial resolution allow plants to be recognized individually or <u>en masse</u>. If plants cannot be individually resolved, or are more easily identified by population, "impurities" will undoubtedly appear in the classification system and in areas demarcated. In the latter circumstances, inaccuracy can be reduced by sample inspection of individuals. Where plants are too small to be resolved, the most outstanding omissions result from inconspicuous species which are rarely abundant but may be widespread in distribution. For example, field observations showed the shrubs <u>Prunus ilicifolia</u>, <u>Rhamnus crocea</u>, and <u>Yucca Whipplei</u> to be widespread but unmappable species of the chaparral association.

Other difficulties stem from distributional variations within each association. Species which occur in concert are referred to as multiples. Each species within a multiple may comprise any proportion of the total, and some may be entirely absent. On the other hand, color and textural signatures of a multiple are a result of distinctive leaf reflectance properties and morphological features of the species

in concert. Additionally, the likely possibility that monoecious stands formed from any one of the constituent species would be identified separately from imagery implies that a multiple reflects a thorough species mixture. Horton's observations of Upland Conifer Forest, for example, indicate that constituent species of the coniferous tree multiple (Pinus ponderosa, P. jeffreyi, Abies concolor, and Libocedrus decurrens) are widely distributed throughout the area he mapped (Horton, 1965).

The theoretical need for transects depends on the accuracy requirements of the map. At the broadest level, each assocation should have representative transects throughout its range (though beyond the scope of this investigation) to convince the reader that certain species actually exist together. A transect across the film is also real since the map is based on imagery patterns. Not only can one designate overlap of species ranges, but also can identify plants either to the single or multiple level. Even unmappable isolates that are "impurities" to the prevailing association may be separated.

7.2.1.7 Integration with ERTS-1

Many on-going investigations have received partial support from both ERTS-1 and the NASA funded "Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques". Such pluralism occurred either because of preparation for ERTS-1 associated investigations prior to satellite launch and program funding or because the nature of the investigation is compatible to data from imagery of multiple scales.

With reference to the remote sensing research activities conducted on the Riverside campus under this integrated study, three such investigations

include: (1) An evaluation of the role of recreation, tourism and homesite environment in modifying the behavior and structure of land and property values. This investigation will focus upon the coast from Oceanside to La Jolla); (2) Development of an environmental data base which will fit into the methodological structure of our information system. Such an information bank would include these topical categories: vegetative associations, wildlife habitats, fluvial and coastal geomorphic processes and features, and any changes caused by human activity; and (3) The demonstration of the feasibility of monitoring cyclic crop production in the Imperial Valley using automated mapping and interpretation techniques. Details relative to these three investigations appear, respectively in the three subsections which follow.

Residential Land Use in Coastal Areas

A major prerequisite to evaluating urban growth is the understanding of the dynamics and the structure of urban land use. Among the most important aspects of urban areas are residential neighborhoods. Many studies have been conducted attempting to explain the structuring of residential types and land values within a city. This section, following in that tradition, has dealt with the behavior and structure of residential land values in small, coastal cities in southern California. These cities, Santa Barbara and Oceanside, represent a common, yet somewhat ignored type of urban area. They are not particularly diverse, functionally. In general, recreation and tourism act as a major force in the economic and social activities of each town. Yet, such towns invariably grow up into larger cities, or are annexed or absorbed by them. The task of this study has been to investigate these two communities,

with specific reference to the behavior of land and property values to at least two stimuli: recreation and tourism; and various environmental attributes which provide amenity value to the homesite, in particular, the various aspects of topography. Clearly, these two factors may not fully explain how land and property values act; therefore, additional discussion is required for cases which do not come under these two influences, and for cases in which other factors may exert substantial influence on a particular tract.

The first step in conducting this study was to develop a method of evaluating the two factors. Recreation and tourism were assessed according to the quantity and quality of their respective features within each census tract. This involved a value judgement in some cases; the resultant explanation was one dealing with the socio-economic aspects of recreational activities and the locational characteristics of certain types of activities. It was determined that certain kinds of recreational or tourist activities would locate, preferentially, in certain kinds of neighborhoods. Evidence suggested that exclusive activities appealed to and would benefit, socially and economically, exclusive or wealthy neighborhoods because their traffic and social patterns are somewhat complementary. Furthermore, high density residential neighborhoods would tend to develop around recreational functions of high density use, the primary examples being beach and marine activities. Here, an assessment of residential structure first surfaced, and would be of great importance in many further explanations. Given these factors, each tract was assessed and rated.

A topographic index demonstrating the environmental qualities of a site which might make it desirable, was reduced to its component parts: (1) slope gradient; (2) elevation; (3) slope orientation; (4) local relief; (5) distance from the ocean; and (6) environmental hazards. Each tract was evaluated in terms of all six component parts and an index value calculated.

It was felt that much of the information needed for this investigation could be readily extracted from imagery provided by NASA and the U-2 flights. In addition to basic land use data, information necessary for the two indexes (recreation and topography) could be drawn from the imagery. Most recreational sites, beaches, golf courses, marinas, etc., could be readily detected. Additional ground surveys were required in order to obtain data regarding the specific characteristics, e.g., whether privately or publicly operated, of each site. The housing and socio-economic structures of the areas could also be inferred, at least in a general sense, by using the NASA imagery. Through the use of a stereoscope, all of the aspects of topography could be, at least, partially evaluated. Precise measuremets of slope gradients and distances, however, required ground level analysis or use of topographic maps. Overall, much of the general and some more detailed information was available on, and extraced from NASA and U-2 underflight photography.

In order to more reasonably determine how each of these characteristics affects land value behavior, it was necessary to examine the general theories of land values in cities. The basic model, in which land values decrease radially outward from a central area, the Central Business

District (CBD), was modified in the following manner. First, the CBD was generalized to refer to a land use which exerted a force of attractiveness, or centrality. Centrality would not be defined as a purely economic force, but perhaps a social force as well. Nor would mere "distance" be the most important factor. Most importantly, the model allowed more than one node of centrality. Thus, in addition to local CBD's, there might be other nodes around which land values reacted. The contention of this section was that the location of recreational and tourist-related activites (a major economic and social function) should exert a substantial influence upon local land values. Furthermore, the amenities created by topography should act as a modifying influence on land values, and certainly property values.

Each tract was evaluated in terms of both the recreation and topographic variables. Regression analyses were performed, and the data were displayed as graphs, tables, and maps. Thus, it was possible to assess their relative roles statistically and graphically, as well as to note the distribution of various characteristics.

From the comparison of the recreational index and land value, it is possible to point to the strong (.70) positive correlation between them. A consideration of the data revealed a specific set of characteristics of the tracts with varying recreational index values and land values. Those tracts which possessed significant quantities of high quality recreational activities tended to also possess the highest land values. This generalization was modified by describing the important attributes of the residential structure of each tract. Among the tracts

exhibiting a high land value and a high recreational index, day use beaches, in association with facilities for high density consumer flow, and high population density, characterized one group while exclusive activities in proximity to high valued, extensive residential areas composed another. Tracts with low recreational index values tended to be low in residential land value, and at times associated with additional non-residential land uses, though not always.

It was further discovered, that, in areas with a high recreational index value, homes and apartments used for seasonal occupancy were very important, compared with non-recreational tracts and the county average recreational index. This function was shown in one or both of two ways: the vacation residence index, and the rent or value quotients. The former simply referred to the numerical availability of vacation homes, which, of course, is not necessarily an absolute measurement of the importance of the recreational function. Certain tracts may fall under private or local ordinance or policy regarding building of such homes. Nevertheless, the rent and value quotients indicate the relative demand for such residences. The fact that, in nearly all of these tracts, the rent or price asked for seasonally-occupied homes is from 15 to 25% higher than the median rent or value in the tract suggests that these homes are being used intensively in accordance with the local recreational attraction. Thus, it is reasonable to conclude that recreation and tourism act as strong positive forces in the appreciation of local residential land values.

The case of topography presented this study with a different problem. The regression analysis and other data displays suggested a rather low

positive (.22) correlation between land value and the derived topographic index, referring to environmental site desirability. While there were tracts which possessed both high land values and site desirability, these same tracts generally had high recreational index values. Those tracts with high site desirability had land values ranging from $1.60 to $3.50 per square foot. However, the relationship between land value and property value was earlier dismissed as unimportant. This suggested that there may be some use in comparing property value and the topographic index rating of sites. While the correlation is not exceedingly high, there does exist a significant trend indicating that the most expensive homes are located on land or sites which are most desirable. The cases in which this was not true were low-valued property. They had rather a pleasant environment and generally were confined to areas near the beach. These tracts are desirable, but located in areas with substantial commerce related to tourism. Such areas also have a high population density. Thus, while the desirability of the site is high (close to the ocean with a good view), the characteristics of the area are not necessarily attractive to those desiring full time occupancy or wanting to construct high valued homes. Such areas are rather more appealing to middle income persons, willing to sacrifice living density for a pleasurable environment. In conclusion, the topographic attributes of a particular site tend to have little direct effect upon land values, but may serve to appreciate the overall property value of a home and site through time. This increase is based upon the larger size of the lots, the tendency to build more expensive homes in

such locations, and the desirability of the site due to its location and physical characteristics.

We may also characterize tracts with low site desirability. In general, they are located on flat alluvial surfaces, with little or no view of the ocean, and generally blocked by hills or mountains. In terms of land use, they tend to be associated with CBD's or industrial activities, which may tend to lower the overall desirability of a site. They may also be adversely affected by flooding and other natural hazards. Property values, in large part, reflect these negative factors as they do the positive factors in more desirable environments.

This investigation yielded some examples which did not fit exactly into the previous analysis. The exceptions fell into three distinct categories: (1) rural, apparently with a rapid on-going conversion to urban residential land uses; (2) industrial/commercial, particularly where light industry is actively competing for land; and (3) educational tracts, in which a university comprises a large or complete portion of the tract's area.

These three situations all tend to appreciate land values. At the same time, neither tract location nor desirability suggests a reason for this land value status. Thus, these cases are exceptional, the land market being the major contributing factor.

Land values and their behavior are products of a complex set of factors. Earlier theories suggesting a single node (CBD) around which they were structured are both outdated and, in the case of specialized urban environments, inaccurate. This study demonstrates the importance of the various factors affecting land values in small southern California

coastal cities. Here, recreation, tourism, and rapidly expanding urban land use in isolated or detached areas are factors which act as additional nodes that modify land and property values in residential areas.

Environmental Data Base

The major objective of this project is to generate a data base reflective of the conditions, processes and important features present along the coastal environment. This research has been undertaken in conjunction with investigators at Santa Barbara where similar data are being gathered for their respective test sites. Although methodologies are similar, final products will vary as the environments represented by the test sites vary. The development of a data base requires that two functions be performed: (1) image (data) interpretation and (2) interfacing of data with a geographic information system. The interpretation function is currently being undertaken in the area of Orange and northern San Diego Counties. This represents Stage II of the process outlined in section 7.1.

The primary data source used in this study has been the high altitude imagery from Mission 164. Since the receipt of the recent U-2 imagery, secondary interpretation and sequential analysis have proven useful in verifying and modifying previous evaluations.

The interpretation process which has been found to be the most efficient and produces the most accurate maps dictates that interpretation and mapping occur on frosted acetate overlays at image scale. These are, then, enlarged, with due consideration given to enlargement

distortion, and transferred to USGS 1:24,000 topographic sheets. Analyses of distortion are still being conducted in order to determine if better methods, within the capabilities of the research group, may be found.

A major stumbling block to successful completion of the product has been that of an inadequate classification system. While numerous systems exist, one must be developed which reflects not only functional distinctions in the environment but also the capability of the various kinds of imagery being used to record these distinctions. Preliminary classifications have been developed, and one is being subjected to detailed experimentation. Ideally, the ultimate form will be not only useful for local analysis but readily adaptable to those utilized by other campuses and the state agencies as well.

The final step in preparing a data base is the digitizing of boundaries and characteristics in a format which can be stored, manipulated and displayed by computer. Among the types of information being recorded are vegetation communities and wildlife habits as well as hydrologic and land use data. When this work is completed, users may obtain comprehensive and accurate surveys of environmental conditions in a variety of habitats.

<u>Agricultural Land Use Mapping and Automatic Crop Identification</u>

The primary objective of this program is to develop and evaluate the feasibility of monitoring cyclic crop production in a large region, e.g., the Imperial Valley, on a routine basis with the use of satellites. The project was initiated in 1969 using Apollo IX imagery of the Imperial Valley. The process of monitoring changes in some 8,000 fields every

18 days will necessarily require the aid of a computer. The system design calls for a human interpreter to indicate whether or not there is a crop in each of the fields. The identification of the type and crop will be performed by the computer, based upon the crop calendar, field size, soil type to support specific crops, regional specialization, and previous cropping. The availability of temporal crop data should enable us to achieve our objective of better than 90% accuracy of individual field crop identification by the fourth or fifth image acquisition pass. Primary output will be a summary of acreage by crop type but the system design will provide the capability to produce thematic maps as a secondary product. Over 90% of the base map has been prepared for digital input to the computer and the design stage of the crop identification system has begun at this time.

Mission 164 high altitude imagery has been of the greatest utility thus far. However, sequential ERTS-1 imagery of the Imperial Valley has been received for three time periods (August 26, September 13, and October 1). Initial examination of the imagery confirms that the condition of any field that is 10 acres in size or larger can be determined from ERTS imagery. The discernible field conditions are: (1) growing crop, (2) wet or irrigated, (3) recently plowed, and (4) bare and dry. False color infrared diazochrome sandwich transparencies are prepared from the system-corrected 9 x 9" positive transparencies. The CIR image is then projected onto a 1:62,500 base map of the area which has each field outlined and indexed by a number code. At present, the condition code is manually transferred to a machine card for further processing.

7.2.2 Summary of Investigations Undertaken in 1972

The following investigations originated since the last annual report of May 1972. Of these, the ones described in Sections 7.2.2.1, 7.2.2.3, and 7.2.2.4 are complete. The others (various parts of section 7.2.2.2) represent programs where environmental monitoring will continue for the duration of the funding period.

7.2.2.1 Barriers to the Diffusion of Remote Sensing Technology

This is an attempt to describe and evaluate the experience of two Los Angeles area governmental agencies with the application of remote sensing technology used to supply information for urban and regional planning. Too often, improvements are made in the state-of-the-art of any technology, and further applications are developed without respect for constraints which many users face when seeking to apply these innovations. Our objective is to examine how the agencies have used remote sensing, and evaluate their experience and results. Future prospects for application are also identified.

The subject organizations are the Community Analysis Bureau (CAB) and Regional Planning Commission (RPC) of Los Angeles City and County governments. Substantial differences exist in origin, scope and authority of their functions, their philosophy, and their position within the local political milieu.

The Community Analysis Bureau. CAB was formed in 1967 as a separate unit of the city government of Los Angeles, funded by a Community Renewal Programming grant from the Department of Housing and Urban Development (HUD) for two-thirds of its costs. The broad goal of CAB

is to prepare a citywide program of community improvement designed to correct existing and deter future blight and obsolescence.

CAB has been authorized to develop a comprehensive information storage and retrieval system which will, in theory, provide effective and timely information to assist on-going city operations -- especially planning and decision making.

Local governments, the Los Angeles area being no exception, have generally been reluctant to implement the concepts owing to their cost, in terms of both the research and the implementation of operational programs. While funds are available from outside sources, many cities hesitate to accept them. Performance criteria associated with federal monies are contrary to a (jealously protected) "home rule" tradition. Social unrest in many central cities (again, the Los Angeles area being no exception) provides crises that are changing these attitudes.

The Regional Planning Commission. RPC administers zoning and subdivision codes for that portion of Los Angeles County which is unincorporated. In that portion, there is a population of 1.1 million. The area comprises 3,020 of the County's 4,083 square miles, largely an urban fringe, vacant, with desert and mountain landscape and without many urbanized areas. RPC has prepared general plans and specialized studies for the entire county including incorporated cities. The State Planning Law has relegated to county planning agencies the functions of planning unincorporated areas and coordinating the efforts of cities to solve broad scale problems. Regional in name alone, its functioning became constrained and complemented by a multiplicity of

organizations which also do planning. Seventy-six incorporated cities besides Los Angeles, with 3.2 additional million persons, comprise the remainder of the County. These cities (an array of special districts, other county departments, and Federal and State agencies, totalling nearly 500 entities) have divided the planning function into a complex pattern. Transportation agencies do transportation planning; water agencies do water planning, etc. This level of fragmentation has so divided the regional planning responsibilities as to make it virtually impossible for one organization to function successfully. As planning processes broaden to encompass regional scales, the scope of authority to implement planning decisions weakens. Jurisdictional fragmentation and the desire for "home rule" are at fault. Each political entity guards its right to control development within its own geographic area. By default, RPC deals with planning the land use of less-structured areas on the urban fringe through zoning and subdivision codes.

Remote Sensing at RPC. Remotely sensed data have been used at the RPC sporadically for nearly 50 years, particularly in the post World War period when the region experienced its remarkable surge of growth. A vast array of site-scale planning decisions had to be made within the framework of the zoning and subdivision codes. Some of these decisions (a small fraction) were made using oblique and vertical black-and-white photographs usually submitted by property developers. The tendency was, however, to base most decisions on field survey data and testimony obtained at public hearings. Aerial photography did not replace traditional ground survey methods of data gathering, but it could and did serve as an adjunct to them.

In the late 1950's remote sensing was applied in the same intermittent, adjunct fashion to long range planning problems involving areas larger than the site scale. Large scale photos and photo mosaics were first used as primary land use data sources during the mid-1960's in the San Fernando and San Gabriel Valley planning studies. Ten years of experience (1955-65) led to greater reliance on remote sensors, but this reliance did not extend to acquiring imagery on a regular basis.

Since 1965, the use of aerial photography increased considerably. Black-and-white photographs were used for the largest county subregion (North County) due to the infeasibility of ground survey. More significant was the application of larger scale aerial photographs to small "community" plan projects of unincorporated areas, and to special, thematic studies of agriculture and other systematic topics.

In 1969, RPC initiated its own contract and acquired color infrared aerial photographs (Type 8443), at a scale of 1:24,000, for a County-wide land use survey. In the 1970's, the emphasis on remote sensing continued to shift from larger to smaller, county-wide, photo scales. Satellite imagery has been employed in public presentations of the county-wide program. In 1971, General Electric Corporation approached the RPC suggesting a joint proposal to NASA to evaluate the possible application of satellite imagery, obtained from the ERTS-A (ERTS-1) program, to urban planning.

Remote Sensing at CAB. CAB applies a systems approach to its task. A comprehensive information storage and retrieval system necessitates the integration of varied data sources within the city into one overall

system. Experience has shown that if geographic data can be spatially identified, they can provide an effective tool for the decision-making process. Since geographic data are seldom static, the information system should be able to produce continuously updated information in quantity, permit periodic evaluations of conditions and trends in the city, allow statistical methods of analysis, and have the capacity for various types of data handling. Then, implications of decisions can be traced by their interaction with other elements of the system. When fully developed, the information system, called LUPAMS (Land Use Plan Analysis Management System), proposes to collect, machine-store, and produce data at the block level. Ideally, information will be tailored to the needs of planners and be available to the largest number of agencies at minimum cost. Large scale (1:10,000) color infrared aerial photographs were recently acquired covering the city and surrounding areas. Steps are being taken to fully integrate remote sensing in an on-going monitoring system that will record housing quality data (the only remotely sensed data currently used) annually at larger scales (1:5,000) for the city's poorer areas.

Planning agencies at the local level represent a large body of potential users of remote sensing technology. Large volumes of spatial data can be obtained inexpensively by aerial photography. Such data can be collected, extracted for various purposes, and stored for further use and historical record more easily, consistently, objectively, and at lower unit cost than data acquired by traditional ground based methods. It is important to clarify why more agencies have not adopted remote

sensing as a research tool and why RPC and CAB have adopted it differently.

Leaders, who may be individuals or groups acting as individuals, determine the flow of information, from what sources it originates, how it is modified, and what purposes it serves. In the case of planning procedures, these leaders represent a greater society -- the cultural milieu in which planning goals and philosophy are defined. This milieu consists largely of a political context that involves planning "publics," where a smaller society -- the planning agency -- is assigned leadership once goals are defined. The smaller agency, in turn, is led by the top management level. A primary problem is that decision-makers have lost touch with the less-involved majority of the population by relying on the political process and on persons concerned with planning (developers, builders, and occasional antagonized citizens). Varied influences come from outside the agency, but those which have maximum impact are extremely local.

Another problem arises because RPC relies on various interdepartmental contacts with the County governmental system where the same local context with similar responsibilities has evolved, producing a closed circle of members stimulating and responding to each other. Contacts with traditional agencies, and the lack of such contact with dissimilar agencies (the CAB and RPC have offices two blocks apart), reduced the input of varied information.

Judgements, values, notions, attitudes, and opinions form a collective frame of reference against which every society measures decisions.

Built-in tendencies to preserve and maintain the status quo and the integrity of past experience result in a propensity to set up barriers against change. Organizations with these tendencies have been identified as having a traditional orientation.

RPC is a traditional agency. Its built-in tendencies long have concentrated manpower and budgets on current planning and on the administration of land use regulations. Consequently, planning has come to represent specialized needs and a unique land development history. New traditions are developing under the influence of a reduced need for current planning, the pressure of planning legislation, and changes in the planning profession, but changes come very slowly.

Ideally, a remote sensing system would provide information for inaccessible or sparsely monitored geographic areas. Such a system is particularly useful for recording those data that are ephemeral or highly mobile. A geographic information system using the synoptic and planimetric qualities of aerial photography has limited utility to site-oriented problems. This is a limitation of research design, not equipment capability. Sophisticated equipment to obtain and process data is practically useless unless one carefully considers the data items themselves, their use, and the design of computer retrieval capabilities. The problem is perpetual. Traditional planning requires information well within the procurement capabilities of remote sensing, but there is little understanding of that capability and even less demand for a more modern form of planning that would require the full potentials of remote sensing techniques.

LOS ANGELES COUNTY: THE JURISDICTION OF THE CAB AND RPC MAP 1

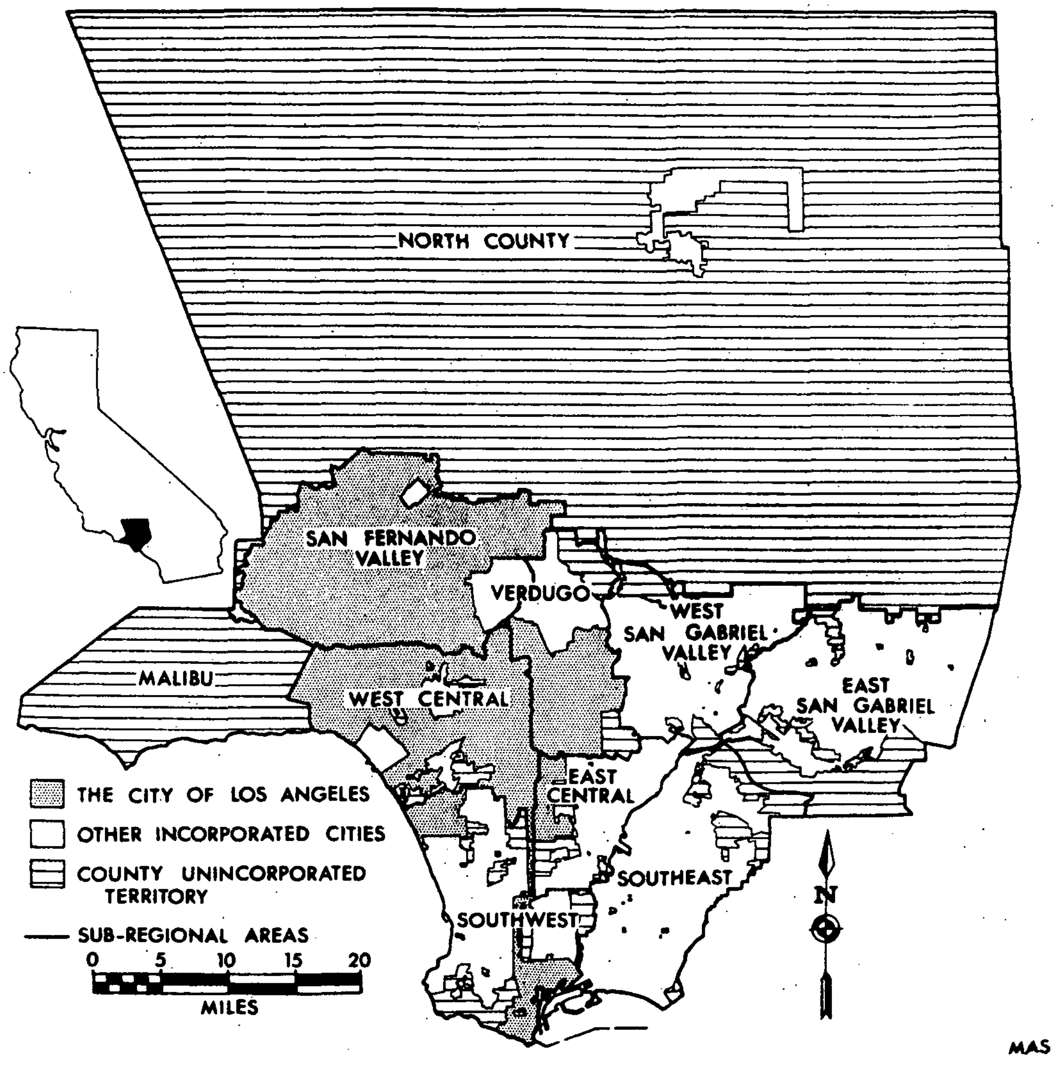


Figure 7.5. Agencies of both the City and County of Los Angeles serve jurisdictional areas which are other than their primary responsibilities. Contract services, including city planning, are provided on a selective basis to many incorporated cities. Major areas under the exclusive jurisdiction of the county are the sparsley populated Mojave Desert and the San Gabriel Mountains (together comprising the North County sub-region) and the Santa Monica Mountains (Malibu sub-region).

Several distinctions must be made. The circumstances under which CAB was formed, its definition of objectives, those who define its objectives, its role in planning, position in the local political hierarchy, source of funding, and duration of work will differ from RPC and other planning agencies. Since its organization and methodology have evolved under unique conditions, it bears little relationship to a traditional agency.

Origin, Objectives, and Role. CAB exists solely to innovate, a task which planning agencies cannot afford to do themselves, and operates because of the federal encouragement which it receives to modernize planning functions. By nature of its assignment, CAB deals with traditionalism daily while integrating varied data files in order to pursue its innovative task. With indirect involvement in decision-making, CAB operates relatively free of local political influence except for the City's share of support where they are vulnerable and expendable, like most research agencies. The problem is that they are not bureaucratic enough, and lack built-in tendencies for self-preservation owing to the short-term and terminal assignment, and the City's tenuous support.

Organization and Methodology. Innovativeness requires CAB to relate closely to modern research agencies not only in remote sensing technology but through computer technology, mathematics, and the social sciences. Its information chain ranges widely. It relies on traditional agencies for data but not for methodological and conceptual stimuli.

Underlying these differences is the scope and philosophy which is fundamental to CAB's purpose. "Social" planning strives to compensate for

the failure of "physical" planning: to resolve major issues in welfare and problems concerning the human element. Over the years, planners tried to integrate the two philosophies with little success. Developments in remote sensing techniques enable data to be acquired systematically and economically over large areas. A geographic information system marries the two technologies in a fashion that simplifies "physical" planning information needs and offers techniques which greatly reduce the information demands of "social" planners.

These organizations provide extreme examples of the use of remote sensing, as one of the data inputs in an information system, and as an illustrative, supplemental, and occasionally primary source of information for every-day planning operations. Remote sensing has potential beyond CAB's present use (housing quality). It can be applied as an information system that monitors and observes many qualitative parameters in the environment. RPC has made more varied uses of remote sensing, but the level of reliance upon and integration of such data in planning programs is far from complete. It remains an intermittent, piecemeal, weakly conceived graft into a persistent manual technology of land use analysis that is "cosmetic" in nature and which is used to "tidy-up" after studies are done by other methods.

<u>Recommendations</u>

1. Remote sensing techniques should be incorporated in a systems approach for full utilization.

2. Personnel should be trained in the acquisition and application of remotely sensed data.

3. Fragmented governmental research functions should be consolidated and pooled to eliminate duplicate efforts and to accumulate both the demand and capital outlay necessary to justify modernizing the information system.

4. Opportunites should be provided for practical demonstrations at workshops, schools of planning, and symposia for contact between scientists and users. An information disseminating system could be developed, addressed to key personnel in user-agencies and interested personnel at lower ranks. This information must transcend the language barrier between scientists and users.

Prospect

Considerable potential for uses of remote sensing techniques exists in advance planning procedures. Problems are many. Not all of the advantages of remote sensors are fully appreciated. Misapplications in the past have led many agencies to doubt the utility of remote sensors. The fault lies with an inability to justify special flights necessary for best results (e.g., temporally adjusted with census-taking, or technically precise) for imagery used only for land use data. Site-orientation plagues advance planners to the degree that land use data for large areas are collected by field survey. Another problem is that plans are seen as terminal, twenty-year forecasts of land use without a concept of phased land development, and involving only objective environmental criteria. Essentially, the difficulty is a restricted concept of advance planning. With pressure all around for modernizing the methodology and broadening the scope, however, there is hope for

change. Remote sensing offers distinct and unique advantages dealing with environmental issues where policies must be based on qualitative data. It permits the establishment of standard or universal observations and criteria for change. Such observations at frequent intervals reveal precursors of change and trends where one can search for root questions or determine probabilities. It permits continuous planning (monitoring, updating, surveillance of hazards) at regional scales. And, aerial photography presents the total visual universe of data (depending on resolution) whichcan be stored as a spatially precise record, unbiased by the investigator's experience. These advantages suggest uses for remote sensing in a different sort of planning than is practiced today.

One way in which traditional agencies have made rapid changes is through crises. Although there are many other crises which are potentially as severe, county planners have lacked crises comparable to the social unrest experienced by many central cities. Such crises weaken the hierarchical structure, and decision-making processes flounder. These events tend to modify the agency outlook.

Urban and suburban problems and demands on planners have increased, but their solutions have become complicated as well. Some technology, such as remote sensing, which simplifies day-to-day procedures and operations will be essential. The crises in traditional agencies have not been severe enough to effectuate change. It is unfortunate that public agencies must face near-disaster before realizing the need to innovate.

7.2.2.2 Environmental Impact Assessment

Stimulated perhaps by growing popular awareness of environmental conditions, one of a series of conservationist outbreaks occurred during the last four years of the 1960's and has continued on a somewhat diminished scale up to the present time. Public interest has waned over the last three years, perhaps as a result of over-publicizing potential environmental problems, or perhaps as a result of competitive advertising by potential polluters. Two laws pertinent to this discussion are outcomes of this latest flurry of environmental concern. One is Federal legislation aimed primarily at government sponsored projects or projects proposed for Federal lands (National Environmental Policy Act, 1969). The second is a California State law and is applicable to all development in California (Sections 21151 and 21152, California Public Resources Code).

This legislation, we can assume, represents an honest effort to cope with and solve the environmental problems of our society. Whether or not it accomplishes these ends will depend upon more than the quality of the legislation itself. The degree of success of the legislation will ultimately be determined by a series of perceptual relationships, where attitudes and understanding of individuals involved in the process of implementation dictate final outcomes.

Remote sensing technology provides a unique perspective from which we may view the manifestations of human impacts upon the environment. NASA regional scale imagery located at the Riverside campus provides data which we have found to be highly useful for preparation of

environmental impact statements (as required by California legislation) for site specific projects within Riverside County (see Section 3). High altitude imagery has also served as a data source for regional impact studies supported by NASA. Subjects of this research include assessment of the impact of off-road recreational vehicles throughout southern California, motorcycles in the Mojave Desert, and the deterioration of desert habitats resulting from urban expansion in the northern Coachella Valley.

Impact of Off-Road Vehicles

The recreational use of off-road vehicles, especially in the arid areas of the western United States, has become an important and rewarding leisure-time activity. As a result, off-road vehicular traffic, especially motorcycle traffic, has already caused considerable damage to these delicate desert environments, and this damage will certainly become more widespread unless regulatory action is taken promptly to prevent overuse and destructive uses of the terrain.

Location of damaged areas and the study of their proliferation would aid greatly in efforts to minimize the impact of this vehicular traffic. Such a study would also provide a rational basis upon which to establish a regulatory policy for off-road vehicles. In this study, the utility of remote sensing techniques for the dual purposes of location and study of damaged area is explored.

Through the use of imagery of California's northern San Gabriel piedmont, spanning the nearly three years from July 1968 to April 1971, all major areas of off-road vehicular damage within the study region

were located. Growth of areas subject to damage, for the time period in question, was also mapped for specific locations.

Small scale imagery (1:100,000-1:120,000) was found to be most desirable for purposes of initial location of damaged areas. Larger scale photography (1:24,000-1:30,000) was found to be more appropriate for more extensive study once damaged areas had been located. CIR imagery, particularly under a stereoscope, was found to be especially valuable in this investigation. Imagery of damaged areas from more than one site is, of course, requisite for a temporal comparison for expansion of damage.

Remote sensing techniques have direct application to the tasks of locating and studying off-road vehicle damage. Aerial survey is clearly superior to ground survey for these purposes for several reasons. First, the use of aerial photographs allows vast areas to be rapidly examined. Second, the perspective offered by aerial photographs allows the interpreter to easily see spatial patterns not readily visible from the ground. Finally, the number of man hours required for a ground survey and mapping of damaged areas probably renders that method prohibitively expensive. Aerial survey, therefore, has a clear cost advantage.

Impact of the Barstow to Las Vegas Motorcycle Race

The most recent high altitude imagery, utilizing the U-2 platform, the RC-10 camera, and color infrared film, clearly shoes the traces of random off-road vehicle (ORV) activity in the Mojave Desert. From this imagery, the extent of the areas of usage can easily be determined, and,

with proper ground study, can reveal the types of environmental changes that have resulted. Simply stated, the premise of this study is: if patterns of random ORV usage can be detected, then surely the traces and environmental modifications resulting from intensive use in a specific area could be determined.

Through communication with the Bureau of Land Management (BLM), it was found that the annual Barstow to Las Vegas Motorcycle Race (consisting of approximately 2,600 riders and 15,000-20,000 spectators) was to be held November 25, 1972 as part of a four-day affair. The BLM was greatly concerned with this event and was engaged in setting up a preliminary study to determine the effects of the race and recommend whether it should be continued. At that time, no aerial coverage was planned by the BLM, their study sites being restricted to ground transects across the route of the race; subsequently, our interest was welcomed and encouraged. The proposed study would monitor environmental changes incurred by the annual Barstow to Las Vegas Motorcycle Race from high altitude imagery. Conclusions would be supported by ground checks and low altitude comparison. Changes could also be monitored over time, as the race is run over a course that differs only slightly from year to year.

The areas affected included the most common types of Mojave Desert terrain; alluvial fans, playas and washes. As will be seen, these areas vary in their ability to accommodate intensive ORV recreational usage and in the amounts and nature of damage that they incur.

Damage that was anticipated, again, varied with the type of material involved. First, the surface soil was expected to be altered. Under

natural conditions, a slight cementing of stable desert surface materials usually occurs because of the net upward movement of water that carries with it dissolved minerals which are deposited at the surface. Weight applied to this surface will necessarily break it, exposing the looser subsurface material. In this process, the surface material is broken, allowed to be transported, and the subsurface material is compacted. The result is a surface with high erosion hazard by both wind and water, underlain by a relatively impervious subsoil. The surface, therefore, becomes denuded of its surface layer, the compacted subsurface promoting the lateral movement of water and preventing, in large part, the germination of plants that could promote erosion control.

This type of effect is likely to be greatest upon alluvial fans. However, the degree of damage is largely dependent upon the portion of the fan that is used. This is necessarily a function of the depositional characteristics associated with stream velocity, slope and channel width. Coarse debris is better able to withstand intensive usage, and is found at the head of the fan since it is the first deposited (a result of its greater weight). Materials increase in fineness and susceptibility to damage as slope decreases or distance from the source increases.

Desert pavement is subject to similar, though less intensive damage, since it is a resistant surface but located on a relatively level area. Once the surface is broken, subsurface material is most susceptible to wind and water erosion.

Playas require a slightly different consideration. Soil textures are fine, but the area serves as the local base level, effectively

eliminating water erosion hazards. The slightly structured playa surface is therefore only susceptible to wind erosion. Perimeters of playas, however, are some of the most likely archaeological sites in a desert environment, and may be subject to destruction.

Washes, in regard to usage, are blessed with instability. Sudden convectional showers that typify desert storms, and the resultant heavy runoff, greatly rework these ephemeral stream channels at frequent intervals. No desert surfaces can form and the coarse sands in their beds resist compaction. Vegetation that inhabits stream courses is also adapted to frequent change.

Much of the damage that is inflicted on these areas results from the preferences of the riders for particular kinds of surfaces over which to ride. Flat or expansive, vegetation free, firm surfaces are most attractive, because they allow greater speed. The qualities of a surface that are attractive to the rider are those which make it most susceptible to damage. The preferred areas are, by and large, fans, playas, and pavement surfaces. Washes, those areas that can withstand heavy usage, are the slower, concentrated parts of the course. Because of the looseness of such areas, riders slow down, and tend to follow single-file.

From examination of previous imagery, it is possible to state that most of the changes observed will be visible on U-2 imagery. From the ground sites that were monitored, the extent of the types of change noted can be plotted and the types of change can be projected for those areas not covered in the ground survey. This change could prove to

be beneficial in some respects (e.g., grazing enhancement) or detrimental to surfaces, erosion potential, vegetation damage and susceptability of grazing animals to possible certain diseases (e.g., valley fever).

It is expected that from this imagery the response to susceptibility to damage of various surfaces and soils in other parts of the Mojave or other arid environments can be predicted. This is one area in which further study will be directed upon receipt of the imagery.

Damage at this point does not appear to be particularly serious or extensive. Though further study may prove otherwise, in consideration of the number of people who derive pleasure from this event, suspension of the event does not seem warranted.

Most important, in those areas that were damaged, there were alternate routes that would have resulted in diminished effects. Imagery of current U-2 scale and resolution will provide a valuable tool in planning future events in the desert in such a way as to minimize damage. This type of imagery will also lead to improved recreational planning of all types in areas where an environment may be so easily damaged.

Habitat Deterioration in the Coachella Valley

Research objectives in the northern Coachella Valley involve the demonstration of high altitude imagery as a useful tool for monitoring urban-rural fringe land use change and associated environmental deterioration. The potential value of this test site is that the land use in settled areas is dominantly urban. The northern Coachella Valley has, as its economic base, tertiary services associated with recreational and

resort activities. The area has (since the late 1960's) experienced continual economic growth, which is manifested in a spectacular transformation of open space to urban land uses.

Previous remotely sensed records of land use in the valley were acquired in 1967 and 1969. These will serve as a historical basis for comparison, and change identification. As of this writing, no decision has been made to utilize capabilities of our geographic information system. Both mapping and graphic display will be accomplished by non-automated methods.

Several preliminary maps have been attempted and completed. Ground truth procedures have indicated that the northern Coachella Valley is an especially compatible area for the use of high altitude data. By using the film as an ultimate source (adjusting the classification scheme to what is visible and not to what is presumed to be there) four different urban and three other categories (seven in all) were identified. The base period for this area is 1966 as detailed land use maps as of that data are available.

It has been determined that increasing human activity is jeopardizing numerous specialized natural habitats in this extension of desert which is most accessible to the densely populated coastal southern California. Most recent land use maps indicate a loss of unique natural habitats, including fan surfaces emanating from the San Jacinto Mountains, the sand dune habitat that extends along the axis of the valley, and the Bighorn sheep habitats in the high desert surrounding the valley bottom.

Continued residential construction has also reduced the habitat value of the valley to man. Increased environmental pollution (air pollution, noise and visual pollution) threaten the area's economic base. Results stemming from the lack of attention to specific recommendations concerning environmental design and impacts of continuing development are apparent through remote sensing techniques. Sequential imagery has recorded the Coachella Valley's continuing environmental deterioration.

7.2.2.3 Comparative Studies in Mass Wasting Phenomena

The purpose of this investigation was to compare, through the use of remote sensing imagery, the effects of heavy precipitation runoff on hill slopes and channelways in two widely separated geographical areas. This was accomplished through a description of the dominant mass wastage phenomena occurring in the two areas of study, (1) the Upper Wildwood Canyon Watershed in Southern California, and (2) the Davis Creek Watershed in Central Virginia. (See figure 5.7.) The description of mass wastage phenomena was based on observations made in the field and on information extracted from aerial photographs obtained for the areas of study. Standard criteria for recognizing and identifying mass wastage phenomena (mudflows and debris avalanches) were expanded on the basis of signature from the aerial photographs available for investigation.

Damage to hill slopes was moderate in the Upper Wildwood Canyon watershed. Complete removal of channel deposits, however, was accomplished in the main channel and a single tributary. Partial collapse of channel

deposits occurred in only three of the remaining tributaries. The dominant mass movement form was a single mudflow.

Damage to hill slopes and to channelways was much more extensive in the Davis Creek watershed. Practically every channelway was affected. Large amounts of rock waste and vegetation were removed from hill slopes within the drainage basin. The main channel of Davis Creek was congested with the debris from hill slopes. Damage to property and loss of life in the watershed was high. The dominant form of mass movement was the debris avalanche, although numerous minor forms of mass wastage occurred within the basin.

Results from the investigation indicate that considerable information related to mass wastage phenomena can be extracted from aerial photographs. Aerial photographs available to the investigator consisted of both Ektachrome infrared and Panchromatic. Photographic scales ranged from 1:5,000 to 1:20,000 and image resolution was fair to good.

Information in detail was obtained from the imagery through the use of an Old Delft scanning stereoscope with a magnification of 1.5 and 4.5 power. The map showing the Upper Wildwood Canyon mudflow is an example.

The criteria developed from photographic images depicted by the available photographs is based largely on pattern, color contrast, and geometric form. Patterns are best reflected in the debris avalanches. Color contrast was helpful in differentiating both forms of mass wastage, but it was particularly useful in differentiating the collapsed channels in the Upper Wildwood Canyon drainage basin from those which were not

LOCATION OF STUDY AREAS

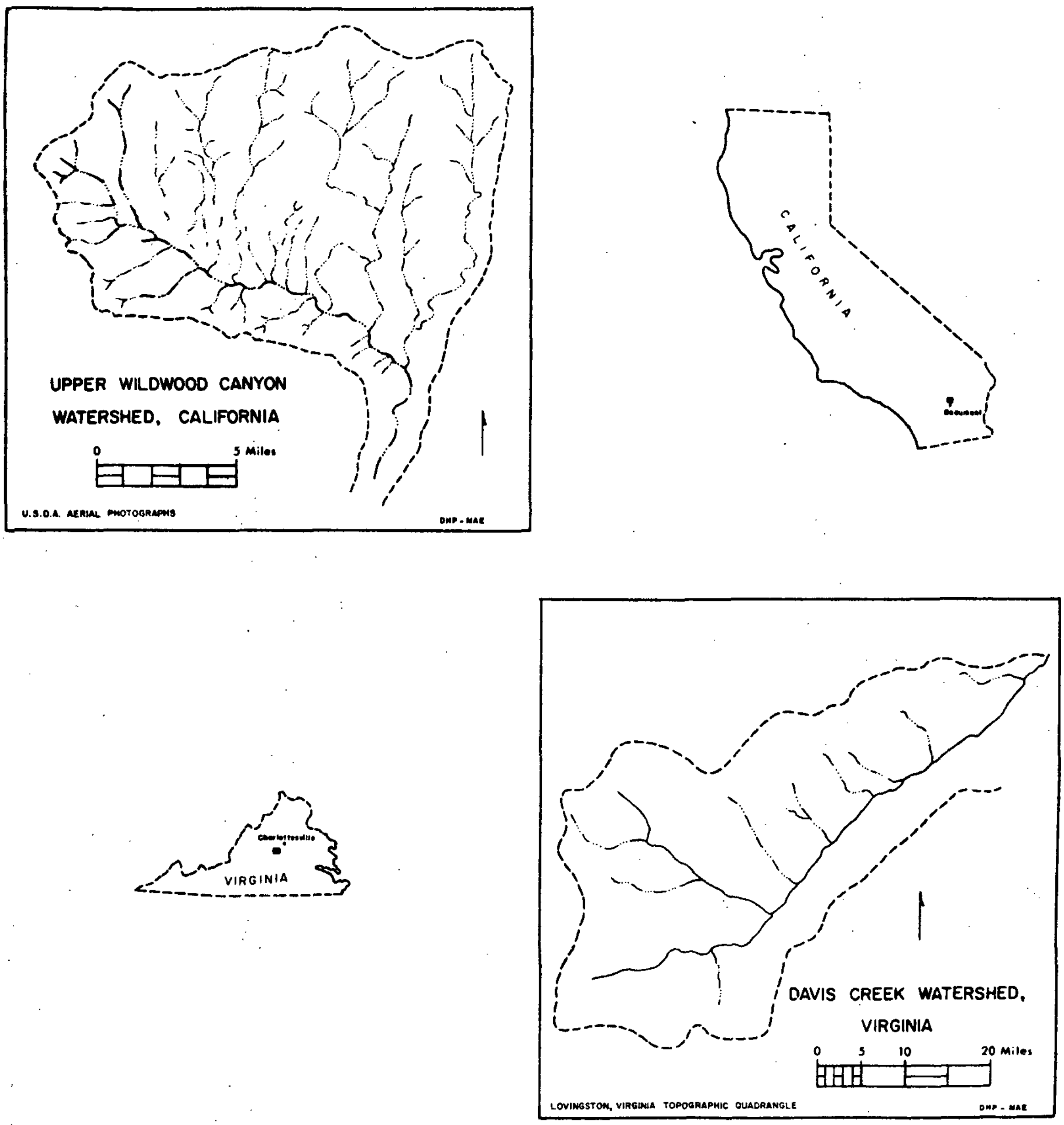


Figure 7.7. Location of the two watershed in which mass wasting phenomena are being studied.

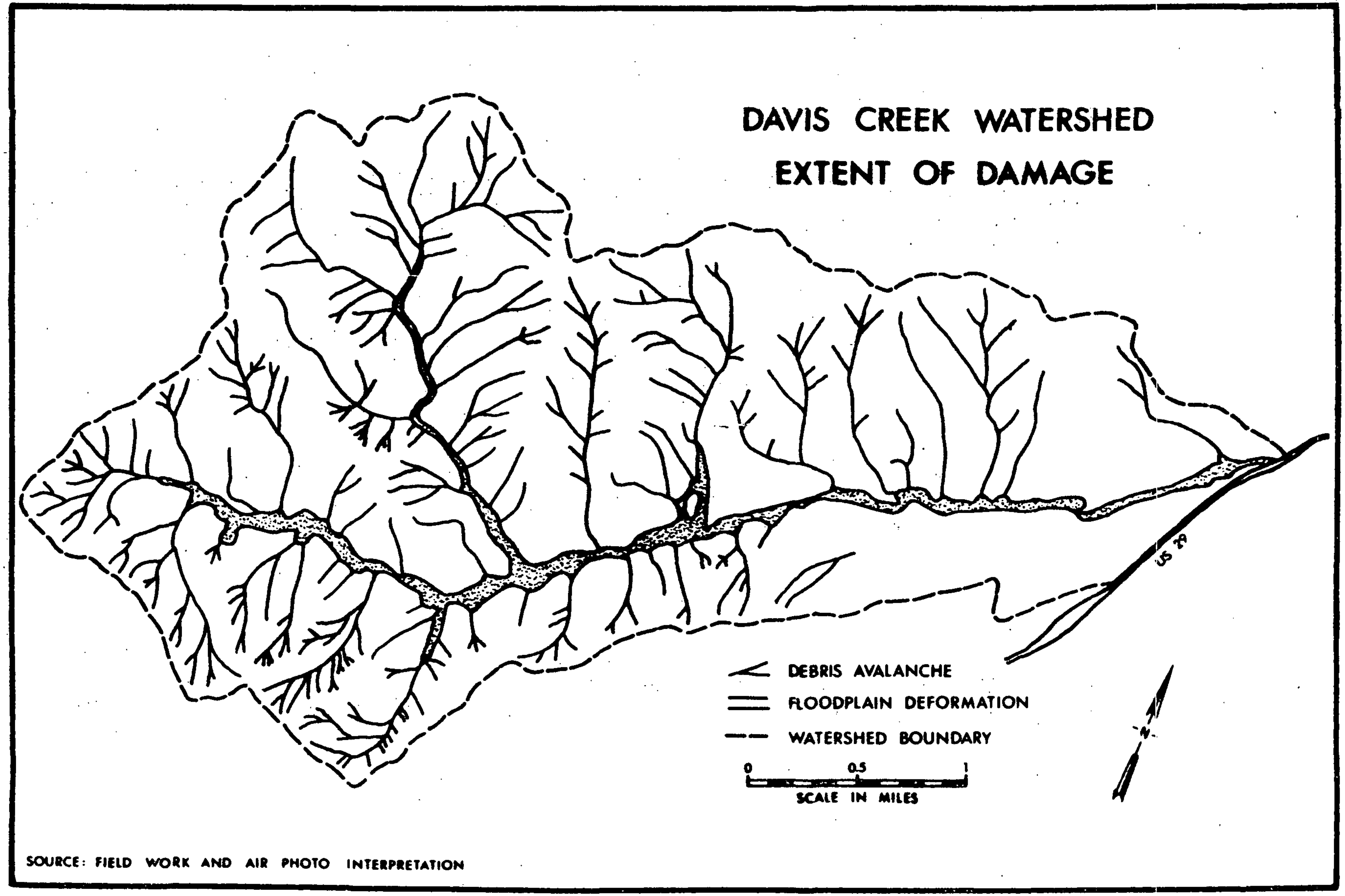


Figure 7.8. Details relative to damage in the Davis Creek Watershed.

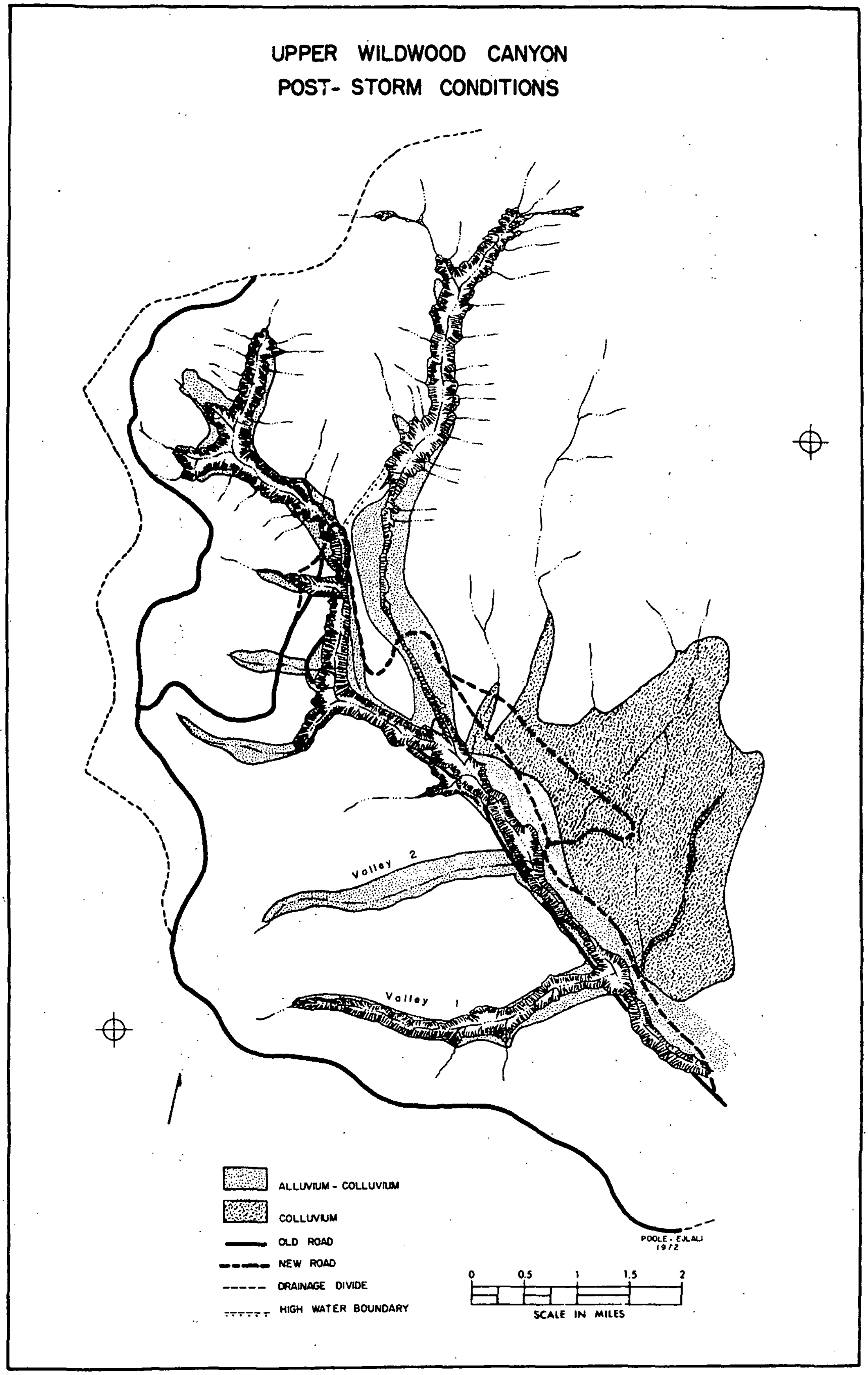


Figure 7.9. Details relative to damage in the Upper Wildwood Canyon Watershed.

TABLE 7.8. COMPARISON OF STORM-RELATED ASPECTS
OF UPPER WILDWOOD CANYON AND DAVIS CREEK WATERSHEDS

Compared Phenomena	Upper Wildwood Canyon	Davis Creek
Dominant mass wastage form	mudflow	debris avalanche
Characteristics of form	channelized; single flow; sinuous in plan, bifurcated; single pattern	channelized; multiple debris avalanches; sinuous in plan; bifurcated multiple patterns
Precipitation input	high	abnormally high
Damage to hill slopes	moderate	extensive
Damage to tributary channels	extensive	extensive
Extent of damage	largely confined to main channel	main channel, all tributaries, and all "feeder" hollows
Types of debris transported	alluvium and colluvium	alluvium-colluvium; ragolith cover; and forest cover
Structural damage and loss of life	none	severe

affected. Geometric form was relied upon most often in recognizing and establishing the identity of debris avalanches.

7.2.2.4 Planning Archaeological Field Research in Coachella Valley, California, with the Aid of Remote Sensing

This brief section of our report discusses a fundamental application of aerial photography to archaeology, that of planning archaeological field research, and using environmental surrogates to locate potential archaeological sites. An example of planning archaeological fieldwork with the aid of aerial photography is the Coachella Valley archaeological project of the Archaeological Research Unit, Department of Anthropology, University of California, Riverside. The project is designated to investigate the adaptive alternatives employed by late prehistoric populations to conditions of environmental deterioration. The project is regionally specific in that it demands a setting which underwent environmental deterioration in the absence of significant climatic change. This specification is necessary because the impact of climatic changes on prehistoric human populations through varying the abundance and distribution of critical food resources is at present difficult if not impossible to assess. Coachella Valley, California provides such a setting in that its lower end was inundated during the Christian era by freshwater Lake LeConte (Blake Sea, Lake Cahuilla) for a probable minimum of 1,000 years. The lake was fed by the Colorado River, and finally desiccated when the river re-routed itself and flowed directly into the Gulf of California some four or five hundred years ago. The prehistoric lake-dwellers, who had previously existed on the relatively stable and abundant lacustrine resources including fish, shellfish,

waterfowl, and aquatic plants, were then forced to adapt to new environmental conditions and a complete reliance on non-lacustrine food resources. It was conceived that certain of the adaptive alternatives employed by the lake-dwelling population would be apparent in the archaeological residues of campsites along the lakeshore and on recessional shorelines which date to the final desiccation of the lake. The problem was then one of isolating intact portions of these shorelines.

While extremely arid, Coachella Valley today, like Imperial Valley to the south, is a region of intensive year-round agriculture. Irrigation water largely derives from the Colorado River and enters Coachella Valley through the Coachella Branch of the All-American Canal system. In Coachella Valley much of the shoreline of Lake LeConte and the archaeological sites along it were destroyed during construction of the Coachella Canal. Since the water is largely distributed throughout the valley by gravity flow, it has been necessary to benchlevel much of the area between the valley floor between and the elevation of the main canal. Thus, a brief review of modern agricultural practices in Coachella Valley made it apparent that a significant portion of the valley floor including the Lake Le Conte main shoreline and recessional shorelines, and the associated archaeological materials,had already been obliterated by "progress." In order to isolate the undisturbed portions of the valley floor which might yield the types of data required by the research design, and thereby most efficiently plan an archaeological survey, it was necessary to consult recent aerial photographic coverage.

A series of NASA color infrared transparencies, scale 1:60,000 and 1:120,000 served as the data base. These photographs proved quite satisfactory for isolating the desired undisturbed areas of the valley floor. On the valley floor proper it was in most cases possible to ascertain from the general appearance and maturity of mesquite thickets whether areas in question were actually undisturbed or whether they had once been under cultivation and since withdrawn from production. Virgin areas meeting the requirements of the research design were located on USGS 7.5' and 15' topographic maps, which were then used in the field during intensive survey. Several hours of time spent in the laboratory examining the photographs was more than sufficient to locate all potential survey areas in the valley, a task which would have required several weeks at great expense in the field.

Since the coverage depicted the landscape as it appeared only 14 months previously, it permitted a more accurate assessment of the potential for archaeological research than the only other fairly recent coverage which was readily available (USDA photographs flown in 1965). In only one instance had an area selected for intensive survey been developed since it was recorded on the NASA photographs.

While a larger scale would have been desirable for the actual location of such features as rock alignments, foot trails, fish traps, house rings, etc., which were ultimately located in the intensive survey of selected areas, the smaller scale proved more than adquate for delimiting those areas. Generally speaking, the smaller scale was probably best since the image could be enlarged and viewed in stereo with the available laboratory facilities, yet it permitted a broader

view which made orientation easier and thus saved time. For the task described here, black-and white infrared or even fine-grained panchromatic films would have probably served equally as well.

This aspect of aerial archaeology, the actual planning of archaeological survey, is of greatest utility to archaeologists whose objectives require them to work in regions that are either substantially developed or that are in the process of being developed. Of course, the major example of the latter would be the alteration of potential archaeological regions by the spread of urbanization. Archaeological surveys of such regions can best be conducted, maximizing data recovery yet keeping field expenses to a minimum, if planning with aerial photographs becomes an integral part of the methodology.

7.3 FUTURE PROPOSED WORK

Efforts proposed for next year by investigators at the Riverside campus are those directed toward: (1) development of a computer based Geographical Information System to include refinement of our Computer Mapping Systems, (2) expansion of our study area to include the western portion of the California Desert, and (3) continued study of the impact on the environment of the Southern California coastal basin caused by the importation of water from the California Water project.

Data which are being produced as a result of the various studies being performed under the Integrated Study are being stockpiled at an ever increasing rate. The ultimate objective of determining the impact of newly imported water into Southern California will be difficult to achieve if these data are not organized into some type of logical information system. The development of computer programs to produce computer

maps has been aimed at arranging the data in some logical order, but only for single categories of data. Our effort in the coming year will be directed toward developing a more flexible Geographic Information System for Southern California in which more than one category of data can be correlated and reproduced both statistically and graphically. A basic problem with the design of a universal information system is the use of a "polygon overlay system" versus a "grid-matrix system" to provide geographical location for area data. The grid-matrix is a less complex system for computer performed correlations, but the data input is a laborious manual process and the output is a graphic display which is not-so-elegant grid map produced by symbols on the line printer. The polygon overlay system poses a very complex computer problem when several different categories of information are being correlated, but the locational accuracy of the data is much greater and the graphic output resembles a true cartographic map. We propose to resolve the problems of both systems this coming year by designing a hybrid of the two systems, thus providing the greatest flexibility for an information system.

Refinement in our computer mapping systems is required to keep pace with the development of the Geographical Information System. The present maps developed to monitor change in the Riverside-San Bernardino-Ontario area are excellent qualitative maps for a single time period evaluation. However, the need is for quantitative mapping of the same area with rapid capability to statistically summarize the total area involved in each land use category and to indicate the areal change of each category

between two time periods. It is proposed that UCR continue to refine the computer mapping systems for thematic map use and to provide more statistical flexibility.

The availability of an information data base will provide the ability to continue the water impact studies in such areas as the Perris Valley. Change in agricultural practices will be monitored with the arrival of water in Lake Perris in May 1973. Correlation of changes in land use patterns can be correlated with other factors such as economics, population, land values, etc.

The receipt of ERTS imagery along with the high altitude U-2 ERTS underflight imagery has now made it practical for the Riverside campus unit to expand the study area to the western portion of the California Desert. The area includes Antelope Valley, Mojave River Valley, and Lucerne Valley. The importation of water in these three areas is already making an impact in many activities including agriculture, recreation, sub-divisions, industrial sites, and energy production. Disturbance of the natural landscape has become a critical problem in the desert. Immediate study of the impact on the desert environment resulting from both human and natural causes is essential in order for county, state and federal land planners and resource managers to make decisions on future uses of the desert. It is proposed that UCR expand the study area to the western portion of the California Desert.

The passage of proposition 20 (environmental control of the use of the California coastline) during the last election makes our integrated studies along the California coast exceedingly important. We

anticipate continuing the coastal basin studies, also, to develop data which can be used by the various regional coastal environment control committees to make decisions involving the public and private use of coastal areas. The environmental studies along the coastal basins are providing the county planners with considerable data to help make decisions regarding the use and preservation of open spaces. The coastal basin studies are providing and will continue to provide considerable information on the phenomena involved with the transition of land from rural use to urban use.

APPENDIX I

Technical Reports Published with NASA Support

T-71-4. Nichols, D. A. (with J. P. Dangermond and R. Postma), "A Demonstration of the Use of the Grid System Utilizing Multi-Source Inputs," August 1971.

T-71-5. Goehring, D. R., "Monitoring the Evolving Land Use Patterns on the Los Angeles Metropolitan Fringe Using Remote Sensing," October 1971.

T-72-1. Poole, D. H., "Studies in Physical Geography: The Deformation Characteristics of Hill Slopes and Channelways in Two Different Environments as Depicted by Remote Sensor Returns," August 1972.

T-72-2. Goehring, D. R. and J. S. McKnight, "Barriers to Innovation: The Example of Remote Sensing in Urban and Regional Planning in the Los Angeles Metropolis," September 1972.

T-72-3. Nichols, D. A. and W. G. Brooner, "Interfacing Remote Sensing and Automated Geographic Information Systems," September 1972.

Chapter 8

DIGITAL HANDLING AND PROCESSING OF REMOTE SENSING DATA

Co-investigator: R. Algazi
Contributors: J. Schriebman, B. Romberger, A. Samulon
Department of Electrical Engineering and Computer Sciences,
Davis and Berkeley Campuses

8.1 INTRODUCTION

An important part of the integrated study of Earth Resources carried out by the University of California is the combined use of all available sensing devices which provide information of interest to earth resource scientists. Two considerations influence the use of multisensor data. Firstly, the data collected in each of several different bands on each of several different dates need to be analyzed in various combinations. Secondly, with the launch of the ERTS-1 Satellite, sets of multisensor data in an electronic format have become available to the project as one of the major data sources. Thus a significant component of our work is the efficient or optimal use of the large amount of data available which has a bearing on the study of specific earth resources. Three approaches are used in the analysis of the available data:

Human Photo Interpretation

Electronic Image Enhancement

Automatic Data Processing

These three approaches complement one another and are all pursued within our study. In order to articulate and understand these different approaches we show in Figure 8.1 a block diagram of the acquisition, analysis, and

enhancement of remote sensing imagery. For each of the features of interest a set of attributes, $\underline{Y}$, makes it possible to study this feature from remote sensing imagery. For instance, the work of the spectral analysis unit of the Forestry Remote Sensing Laboratory is directed toward the study of spectral attributes of vegetation. The work of Coulson and Walraven systematically considers polarization effects of features and natural surfaces. By the time the attributes of the feature of interest have been recorded, in block 3, as spectral images or scans, these attributes have been modified by several partially known or unknown effects. These effects will include, for instance, the mixing of features due to insufficient image resolution, the variations of sunlight illumination, and degradation due to atmospheric scattering and turbidity. The analysis of the resulting imagery will be affected to various degrees by all of these poorly known effects. In some cases, such as the mapping of rangeland resources, the task can be done conveniently by considering a single spectral image or a standard color combination of spectral images. In other cases, such as monitoring water quality, the task is sufficiently more difficult that more sophisticated analysis techniques are needed. In its generality, the study of ground features from remote sensing data falls within the framework of statistical decision and estimation theory. The study of spectral and other properties of surfaces is now called the acquisition of _a priori_ information. The transformation of the attributes of the feature of interest into attributes of the images or scan is a probabilistic mapping. Thus, for a given feature of interest the recorded attributes have a statistical distribution which has to be

taken into account in studying this feature. The number of images per scan can be large, seven for ERTS-1, and the number of observed attributes can be even larger. Thus the intelligent exploitation of the relevant information requires the ability to handle large amounts of data in a concerted fashion. Our group, shown as block 4 in the diagram of Figure 8.1, brings to the integrated study both the experimental facility and personnel with the knowledge and background needed to perform the systematic exploitation of the available information. Such elaborate methods are most pertinent for tasks which cannot be done by direct observation of conventional black-and-white or color combined imagery. For this work, the data processing facility being established as part of the University of California program emphasizes man-machine interaction rather than bulk processing of data. It uses as a central processing element a digital computer; thus the development of use of data processing algorithms becomes principally a problem in computer software development. With this approach, it becomes possible to make use of the very extensive digital computation facility already available at the University of California. By the acquisition of a very modest number of specialized computer peripherals, an extremely versatile and flexible facility is being made available to the program. This digital signal processing facility, also used on other NASA sponsored image processing work, is described briefly later in this report. It will be connected to the CDC 6400 digital computer of the Campus Computer Center.

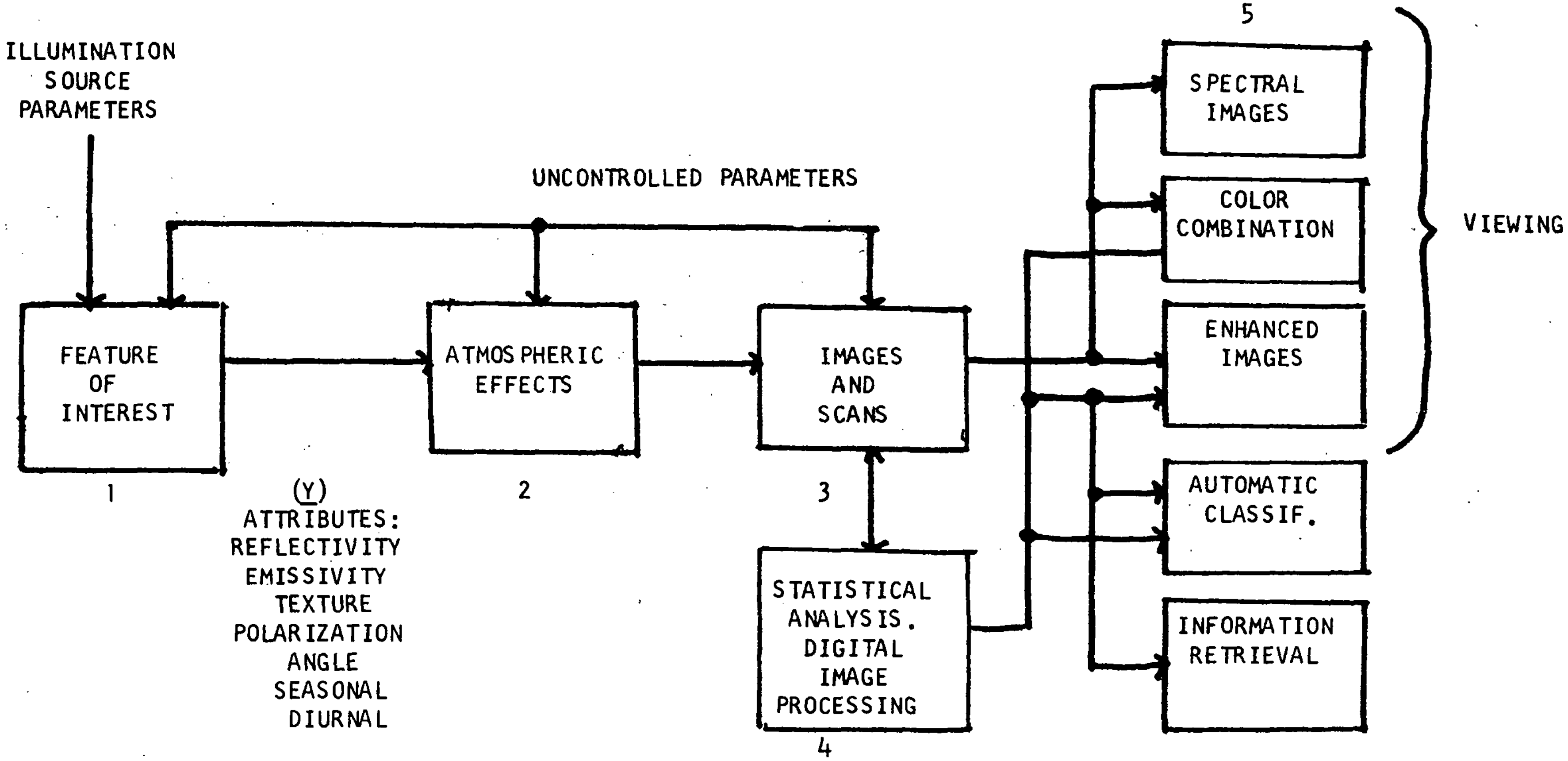


Figure 8.1 Flow diagram of the acquisition, analysis and enhancement of remote sensing images.

Our facility and programs allow us to answer questions such as the following for the various investigations in our integrated study:

1. Which spectral bands and what resolution capabilities are needed in a specific discrimination problem?

2. How should spectral bands be combined to perform feature enhancement?

3. How well can <u>a priori</u> information (e.g., signature analysis) be relied upon to design enhancement algorithms?

To handle these questions our approach is to rely upon ground truth and the images transmitted from ERTS-1. For digitized images a quantitative analysis is conducted of the effect on spectral components as well as on texture of images due to the features of interest. The results of this analysis in the form of one and multidimensional histograms, Fourier spectra, etc., allow us to eliminate irrelevant data, rank the usefulness of relevant data to a specific enhancement task, and guide the design of enhancement programs. Our philosophy is to perform the steps of the analysis rapidly using a small data array, observe intermediate results in color display, and make use of and try to quantify all clues available to a trained observer. This approach is being used with very promising results on ERTS-1 data, as we describe later in this report.

8.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

The progress to date on our part of the integrated study can be divided into the following broad categories:

1. Minor hardward modifications and improvements in the digital image processing facility central to our work.

2. Development of a very flexible programming system for interactive image handling and display.

3. Development of a systematic image enhancement procedure applicable to a variety of problems as well as to remote sensing.

4. Application of the procedure of 3) to ERTS-1 data and enhancement of imagery of interest to several participants of our integrated study.

5. Articulation and investigation of some of the basic issues which underlie the interactive enhancement of remote sensing data by digital computers.

8.2.1 Digital Processing Facility

The facility is shown in Figure 8.2 and is now operational. Three modifications of the Image Processing Facility are still underway.

1. Replacement of a student-built high resolution B/W display by a purchased unit of higher quality and better reliability. Some hardware modification is being carried out to increase the speed of display and to provide capability for color photography through color filters.

2. Acquisition and interfacing of a head-per-track digital disc storage. This unit will increase significantly the amount of rapid access digital storage available to us. This will result in a significant increase in the speed of several of the image processing algorithms we commonly use.

3. Completion of the High Rate Data Link to the CDC 6400 on Campus is still pending, in part because of manpower limitations and

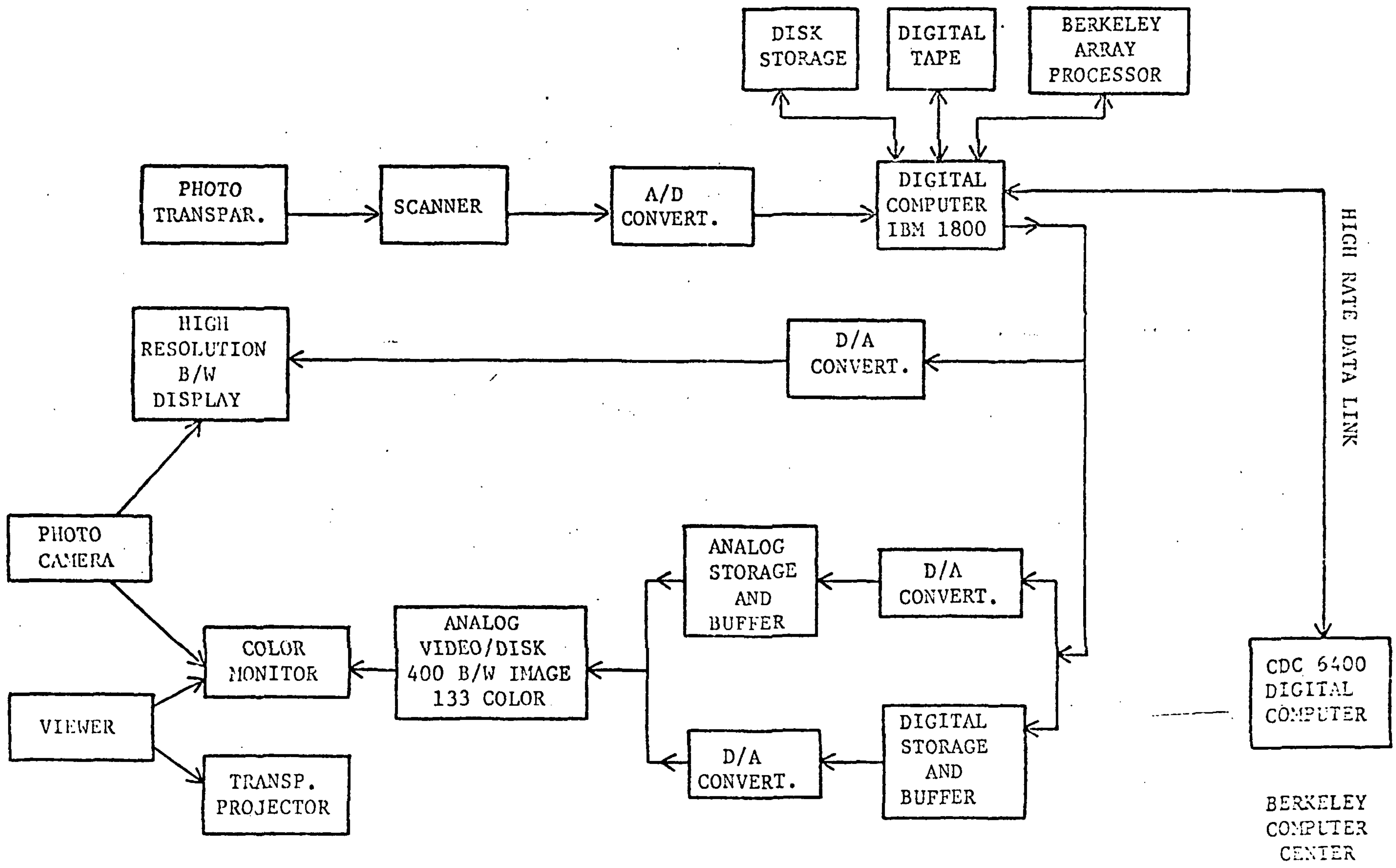


Figure 8.2. Digital Image Processing Facility

in part because of the delay in the work of the Berkeley Computer Center required for the operation of the link.

8.2.2 Picture Processing Programming System (J. Schriebman & B. Romberger)

General Description

Due to the large number of specific operations of interest in our work, it is necessary to provide a framework for the organization of user oriented image processing programs. To this end an image processing system has been developed.

The programming system can best be understood by considering a typical experiment. The investigator has an idea of what operations are necessary on the data to get the results he wants but is not usually sure of the exact parameters. He takes a sample data block and performs the series of steps necessary, thereby obtaining an initial set of results using his estimates of the parameters. Based on an analysis of these results, the steps are performed again with altered parameters or possibly even with an altered procedure, and the new results likewise are studied. After a number of such tries, a procedure is developed which gives the best results. This procedure is then used on other data blocks.

Without some sort of programming system, each step in the above procedure requires one to start execution of the proper program and to enter the data and parameters. It also requires one to keep track of intermediate results that are needed later and to set up his own data storage. Consequently, a system has been developed to eliminate much of the work involved with these manual operations.

The basic requirement of the system is that it will permit interactive usage. During the trial phase, each step is performed as the

user presents it to the system with intermediate results readily available so that he can tell how well the procedure is working. He then runs through the entire procedure to look at the results. The procedure can be repeated with modifications or changes in the parameters to see the effect on the results. Once a procedure is finalized, it is possible to repeat it on a series of data blocks.

A second requirement of the system is that it be easy to use. The user is able to sit at the console and type in the commands that tell the system what parameters to use. The syntax is fairly easy to understand and yet it is not overly restrictive or hard to expand.

A number of secondary user objectives are also met by the present system:

1. Parameters with a commonly used value have default values so that they do not have to be entered every time.

2. Parameters with restricted values are checked for validity.

3. Results (such as max or min) from one step are usable in further steps without requiring the user to remember and enter them.

4. The user is able to interrogate the system as to what programs are available, what data are presently accessible, what values the various parameters have and what parameters are required for each program.

5. Once the user determines a procedure, he is able to set up a whole series of commands for the system to execute without its requiring his intervention at every step.

6. The system handles data storage space allocation unless the user wants to intervene.

A third requirement of the system is that new processing programs can be added easily. This requires an easy procedure for telling the system what new program has been added, what its parameters are and their restrictions, how to set up data files or where to find input files, and what comments to give the user if he requests information on the program or its parameters.

A fourth requirement is that the system be easy to implement. A balance must be reached between features wanted and difficulty of implementation. The system is designed in such a way as to make check-out convenient, but is also flexible enough to make the introduction of modifications and additions fairly easy.

System Components

The system itself consists of a group of FORTRAN and assembly language programs that interprets the user's commands, chooses the proper processing routines to call, passes them the correct parameters, and does a variety of bookkeeping functions for the user. The following components are important for the user:

1. FILES - Data blocks stored on bulk storage devices such as disks. These can be real picture files, frequency domain picture files or general data files such as filters or maps for displaying pictures.

2. USER LANGUAGE - The language with which the user communicates his wishes to the system. The language is basically FORTRAN-like but geared to the special purpose for which the system was designed.

3. PROCESSING PROGRAMS - Routines callable by the system which are designed for the individual step that is to be performed such as fast fourier transform, video display of a picture, filtering, selection

of a sub-section of a picture, etc. If the user has a task for which the system has no processing program to call, the user may write such a program and add it to the system by a fairly simple mechanism.

<u>The System User Language</u>

Constants in the system can be integer, real, or complex. Integer and real constants are the same as in FORTRAN. Complex constants are two integers usually separated by a slash sign (/). Variables (integer, real, complex, or data files) can be simple or can have up to three subscripts (subscripts start from one as in FORTRAN).

Expressions are any combination of non-file variables, constants or functions separated by any of the signs ("operations") +, -, *, /, **, =; and may be parsed by parentheses. Mixed mode expressions are allowed. Array subscripts and function arguments can be any valid expression.

Examples: A+B

I=J=K+L*M**N

C(I,J)

C(C(I,J),SIN(PIN/2))

D(I=I+1)

Functions presently available are:

name	args	result type	use
SQRT	1	real	square root
EXP	1	real	exponentiation
ALOG	1	real	log base e
SIN,COS	1	real	sine or cosine

TANH	1	real	hyperbolic tangent
ABS,IABS	1	int,real	absolute value
ATAN	1	real	factorial
MAG	1	integer	magnitude of a complex number
IAND IOR IEOR	2	integer	and, or, exclusive or
MAXOF MINOF	2	integer	maximum and minimum

Commands are of two basic types -- an assignment statement and a subroutine-type statement. The assignment statement is just an expression with the assignment operator (=) as the left most operator. A subroutine-type statement consists of a name specifying the operation followed by a list of parameters for the routine. The parameters can be any valid expression. If a ? is entered after the operation name, general comments about the routine are displayed and a comment on each parameter is displayed before the parameter is entered.

Example: SCANP SIZE PFILE MIN MAX,,,1500

Scan a picture from the mechanical scanner of size SIZE X SIZE into picture file PFILE putting the maximum and minimum values in MAX and MIN, defaulting the step size parameters and scanning at a velocity of 1500 steps per second.

The two modes of operation are interactive and automatic. In interactive mode each command is executed as it is typed in. In auto mode an entire program of commands is typed in, then executed later by a special command.

System Commands presently available are:

HELP - display a list of commands available

INT, REAL, CMPLX, FILE - set up variables for the user

DELETE - delete a variable

ASSEL - assign data storage space under user control

RELSE - release storage space

ASIGN - assign the input or output device

input from keyboard or cards, output to typewriter storage scope, or printer

DEBUG - special debugging aid

EXIT - exit from the system

GOTO - jump of control to another part of the program

IF - conditional jump of control

DO, ENDO - repeated execution of a group of commands (can be embedded to a depth of 20)

REDI, READR, READC, WRITE - read or write a variable

READI, WRITF - read or write a file (data block)

WRITS - write a string of characters

STAT - display system status

PAUSE - pause in execution until START is pressed

RESET, INITL - used to reset system variables

TRACE - set trace flag for system debugging

AUTO, END - delimit an auto mode program

STOP - stop execution of an auto mode program

XEQ - execute an auto mode program

KILL - terminate creation of an auto mode program

ALTER - make changes or entries in the commands available to the system

Example of System Use

Suppose the user has a picture that, due to the type of exposure, exhibits significant shading so that one side is lighter than the other. One usable procedure for correction is to transform the picture into the frequency domain, high pass filter it, then transform it back into a real picture and display it. Card starting with a * are comments on the commands that follow.

```
*SET UP AN INTEGER ARRAY OF LENGTH 256 FOR GENERATING THE FILTERING
INT A(256)
```

```
*SET ALL FREQUENCIES BELOW 10 to 0
DO I=1,10
A(I)=0
ENDO
```

```
*SAVE THE FREQUENCIES ABOVE 10
DO I=11,256
A(I)=32767
ENDO
```

```
*WRITE THE ARRAY ON A DATA FILE FOR USE AS A FILTER
WRITE A FILTER
```

```
*TRANSFORM THE ORIGINAL PICTURE INTO THE FREQUENCY DOMAIN
FFT 2  8 PIC FREQA  FREQB
```

```
*FILTER THE PICTURE
FLTML  256  FREQA  FREQB  FRGQA  FREQB  FLTER
```

```
*TRANSFORM THE PICTURE BACK INTO A REAL PICTURE
IFT 2  8  PICF  FREQA  FREQB
```

```
*DISPLAY THE PICTURE
PACK 256 PICF  PACK
VIBE 256 PACK
```

8.2.3 A Systematic Image Enhancement Procedure

A systematic approach to the enhancement of images has been developed. This approach exploits two principal features involved in the observation of images: the properties of human vision and the statistics of the images being observed. A fairly detailed exposition of the technique is presented in Appendix 1. The rationale of the enhancement procedure is reasonably simple: in the observation of some features of interest in an image, the range of objective luminance-chrominance values being displayed is generally limited and does not use the whole perceptual range of vision of the observer. The purpose of the enhancement technique presented is to expand and distort in a systematic way the grey scale values of each of the multispectral bands making up a color composite, to enhance the differential visibility of the features being observed. Thus, the enhancement is feature dependent, and the work proceeds in the following steps.

1. Extraction of a geographic area of interest from NASA CCT and reformating for subsequent work.

2. Display on a color television monitor of standard color composites, to check for misregistration and to select subareas with features of interest.

3. Generate histograms in each of the spectral bands for subareas of the image which include features of interest. For instance we may

wish to obtain maximum visibility in the water to monitor water quality and various types of water pollution.

4. Generate an enhancement table for each of the spectral bands corresponding to the histogram of intensity values in that band.

5. Apply the enhancement tables to one or several of the spectral components and display the enhanced images for visual observation.

6. Return to step 4 to modify enhancement table, etc.

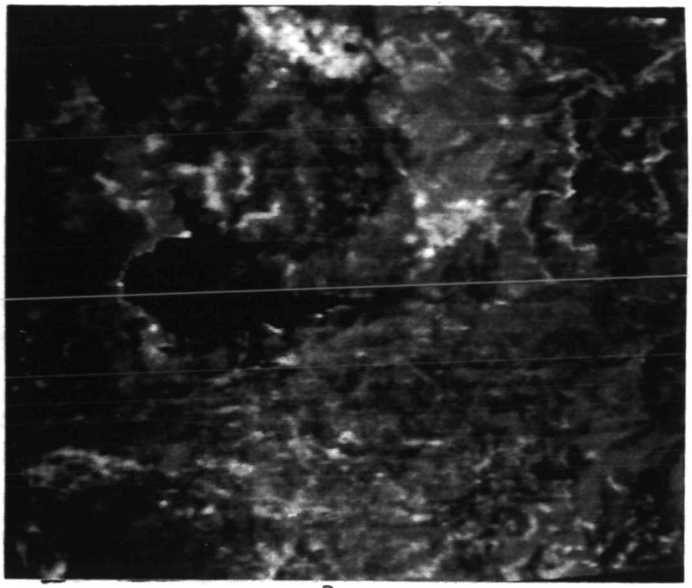
Some properties of the enhancement procedure are of particular importance in remote sensing applications.

1. Enhancement of multispectral images, once they are reformatted to the requirements of our image processing facility, is extremely fast. One iteration does not require more than a few minutes ($\leq$ 10) for a 256 x 256 set of images. Therefore, substantial interaction with the data is possible.

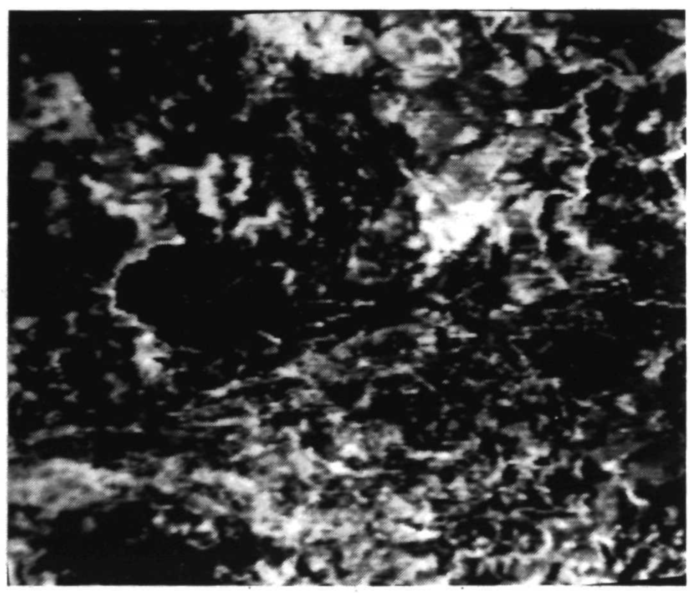
2. The procedure does not presume a certain number of classes (crops, vegetation types, etc.) to be distinguished. It will provide enhanced visibility of whatever is present in the subarea on which the enhancement algorithm is designed. Thus it is a very powerful experimental tool for discovering new patterns and relations not anticipated by the investigator. This will be illustrated by examples in the next subsection.

8.2.4 Application of Digital Enhancement Procedures to ERTS-1 Data

The proceudre described in Appendix 1 and in 8.2.3 has been applied to several geographic areas that are of interest to other participants in our integrated study. We illustrate some of the results obtained with ERTS-1 data.

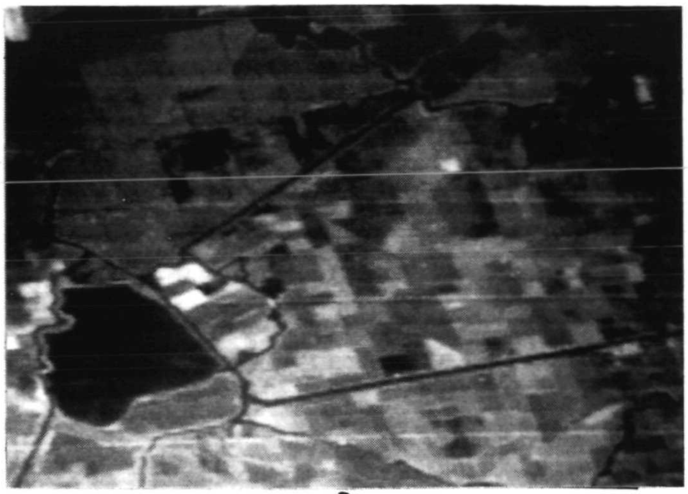


a.

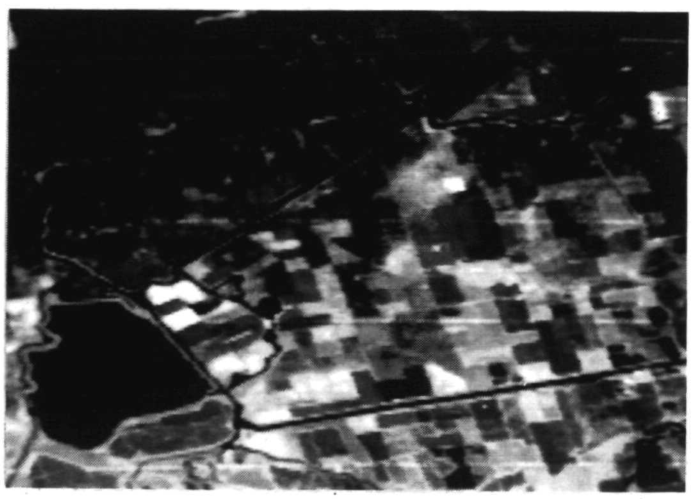


b.

Figure 8.3. Bucks Lake, MSS Bands 4, 5, and 7. a. Standard ERTS-1 color composite. b. Enhanced ERTS-1 color composite.



a.



b.

Figure 8.4. San Joaquin Valley, MSS Bands 4, 5 and 7. a. Standard ERTS-1 color composite. b. Enhanced ERTS-1 color composite.

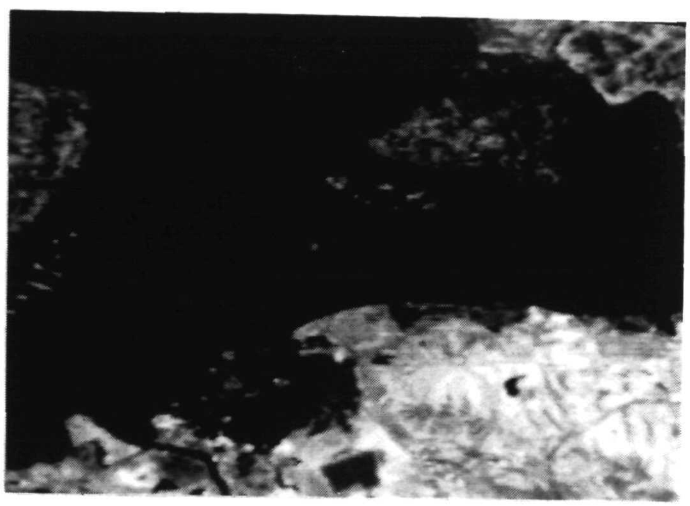


Figure 8.5. Suisun Bay. Enhanced ERTS-1 MSS Color Composite
(Note fleet of ships on left side of bay)

1. Bucks Lake, frame 1002-10125

A standard color composite of MSS bands 4, 5, and 7 is shown in Figure 8.3a. A fully enhanced image is shown in Figure 8.3b.

2. San Joaquin Valley. ERTS-1, frame 1003-18175

In this agricultural area a standard composite of MSS bands 4, 5, and 7 and an enhanced composite are shown in Figures 8.4a and 8.4b. In addition to a striking improvement in the differential visibility of features by enhancement, one observes, in the centers of the image a yellowish pattern which encompasses several fields. This underlying pattern may result from a loss of vigor due to salt extrusions, as discussed in Appendix 2.

3. Suisun Bay, frame 1003-18175

We show an enhanced composite of MSS bands 4, 5, and 7 for Suisun Bay in the Sacramento Delta Region. The enhancement was principally designed to improve the visibility of features in the water. We observe significant patterns in the water due to various concentrations of contaminants or sediments. In subsequent work, not illustrated here, we have been able to obtain significantly better results on this point.

A graduate student, Alfred Samulon, has started some work on the application of digital techniques to the enhancement of salt patterns in soils, principally in agricultural lands. This work is described briefly in Appendix 2.

8.3 FUTURE PROPOSED RESEARCH

The work undertaken and the results obtained correspond to two major directions in our activities: (1) The development of digital

processing algorithms directed to the interactive enhancement of multispectral data, and (2) the use of these techniques for remote sensing applications.

The development of digital image processing algorithms for enhancement purposes follows the general framework outlined in section 8.1 and has four specific objectives:

1. The extension of the techniques of image enhancement by grey scale mapping reported in Appendix 1 to take into account the dependence of the spectral components on each other. Thus, spectral components may be enhanced jointly rather than independently as is currently done.

2. The handling and display of more than three spectral components for visual inspection. Currently the approach with ERTS-1 data is to discard MSS band 6 or MSS band 7 in color composites according to the application. This is not the only choice available. A more systematic and rational approach to this problem is possible. Some results on dimensionality reduction have been reported by personnel of LARS at Purdue in the past year. These and other approaches will be pursued with primary emphasis on speed of computation and interactive use.

3. The enhancement of images to provide maximum visibility of boundaries of features. For instance, in current applications of ERTS-1 data the delineation of urban areas and their growth is of importance. Although the global enhancement techniques of Appendix 1 will provide some help on this problem it is not specifically designed for the task. Specific boundary enhancement techniques will be developed and implemented.

4. Measurement and correction of the atmospheric degradation of images.

A significant problem in the sequential monitoring of earth resources is the time variable degradation of images by atmospheric effects such as haze, scattering etc. Some work will be undertaken to measure and correct these effects on remote sensing images.

In the applications of image enhancement algorithms to earth resources several specific objectives will be pursued.

1. Enhancement of patterns of salt-affected soils. This problem is described in Appendix 2 and will be continued during the coming year.

2. Measurement of the albedo in parts of the State of California. This project, proposed by Dr. K. Coulson of the Davis Campus, will make use of ERTS-B data. A substantial amount of the work will involve digital processing of the data. In this project, our work will assist in the development of algorithms and the execution and display of pilot runs.

3. Other participants in our integrated study are proposing the inventory and delineation of various earth resources relating to agriculture, water management and quality, etc. As we are currently doing, we shall keep ourselves informed of their efforts and provide assistance in the form of enhanced imagery.

Appendix 1

Image Enhancement by Grey Scale Mapping

V. R. Algazi

Introduction

The visual inspection of images of natural objects or of artificially generated images to provide qualitative or quantitative information is one of the most common activities in science and engineering. With the advent of the digital computer as a useful image processing tool, black-and-white images with a grey scale, (as well as color images) with multi-dimensional surfaces can be precisely manipulated before display to provide the viewer with an improved visibility of features of interest. The visual inspection of images to provide quantitative information is constrained by properties of human vision. The dominant properties are an excellent spatial resolution and a comparatively poor resolution to light intensity variations. For color vision, an important property of the eye is the ability to distinguish a large number of color hues. This good resolution in the color dimension is exploited in pseudocolor presentation in which the grey scale of a black-and-white image is mapped into color for improved visibility.

In this appendix, we consider several aspects of the enhancement of grey scale images by mapping into grey scale or color images. We are interested in the monotonic mapping of the grey scale of an image. By monotonic we mean that the order of grey scale values is preserved in the mapping into a grey scale or that the grey scale values are mapped into a fixed and readily identifiable order of color hues. We do not

consider mappings designed to enhance differences among some features of an image and which may result in destroying all information on other substantial portions of the image.

For our defined task, elementary consideration of properties of human vision lead us to propose new enhancement methods for "optimum" image visibility. Another family of enhancement methids is then discussed which also takes into account statistical properties of the images themselves.

Conditions of the Study

Since we are concerned with physical attributes of light and color and also with attributes of light and color sensations, some terminology which differentiates objective and subjective aspects is needed. For the objective aspects we shall use the formalism of colorimetry in terms of a defined "standard observer" and color-stimulus specification in terms of tri-stimulus values [1]. Thus. luminance is a measure of energy while brightness will denote the corresponding sensation. The dominant wavelength in the spectrum yields a sensation of hue. The purity of the color excitation is related to the sensation of color saturation. We can thus draw the following convenient diagrams.

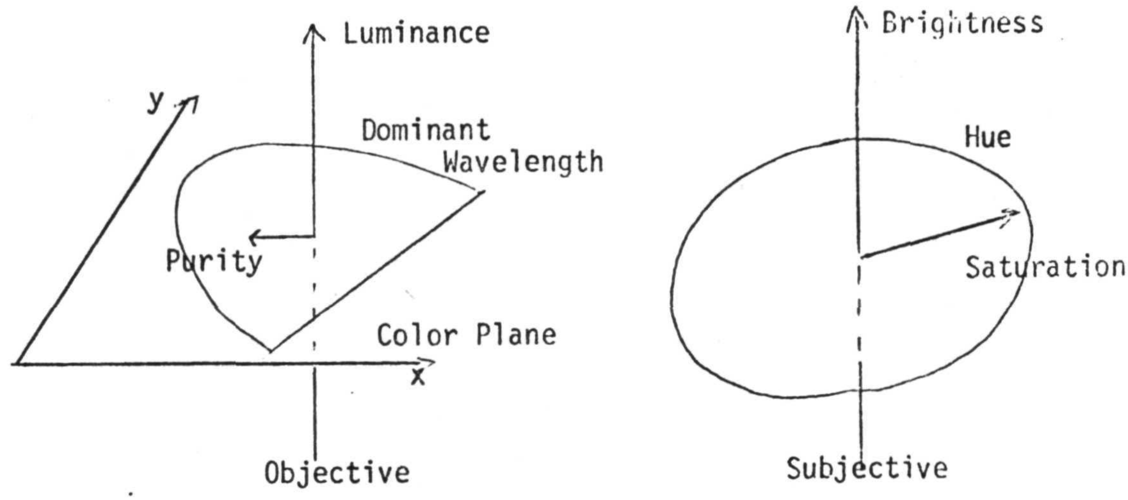


Figure A-1. Relationships between objective and subjective color spaces.

What we hope to exploit, for the purpose of image enhancement, are some elementary aspects of the extensively studied relationship between the objective and subjective spaces. Since one is always confronted with a number of techniques for the recording, reproduction and display of images, we shall ignore, in its major part, that aspect of the problem. We shall assume that the techniques for the recording and display of images are not limiting the range and resolution of luminances reproduced. For the color rendition, we have to refer to specific color primaries, and we shall use the standard NTSC colors.

We thus consider a limited part of the image enhancement problem, as shown in the diagram below.

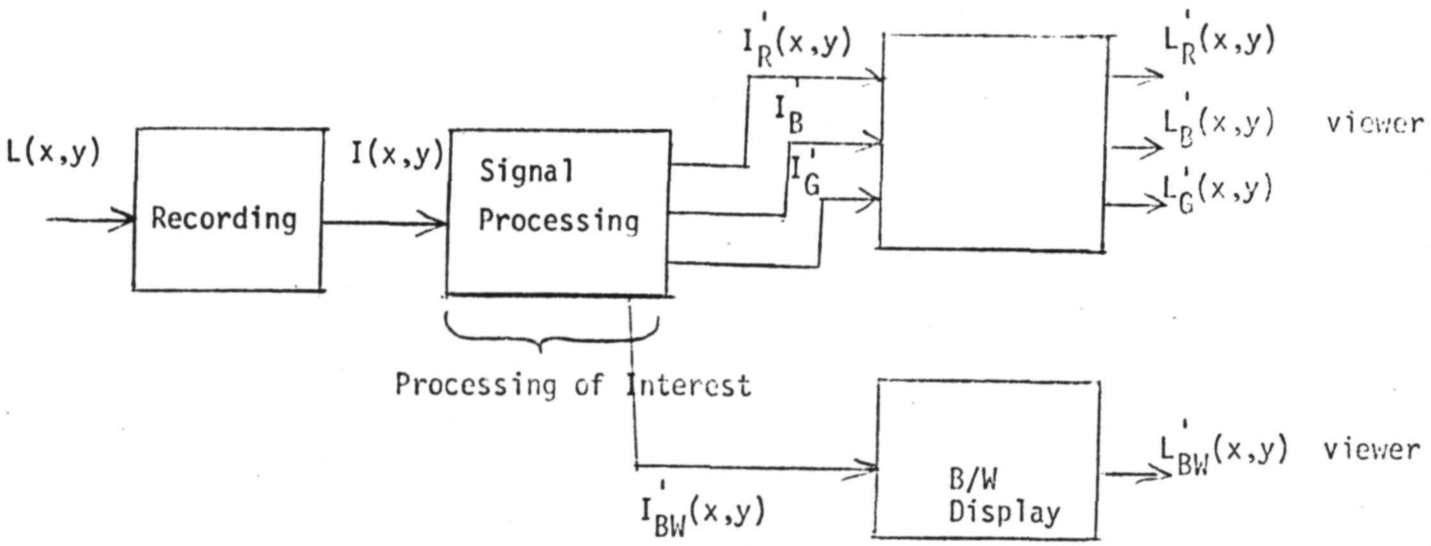


Figure A-2. Considerations involved in image enhancement.

If the recording system and display introduce nonlinear effects of their own, these can be compensated to a substantial extent by signal processing, but such compensation depends on the physical devices used. Here we shall assume that the intensity variables I and the luminance variables L

are proportional. Note in the diagram that $L(x,y)$ could refer to an arbitrary surface, not necessarily related to a physical image.

Referring to Figure A-2, we can now describe more precisely the problem of interest. We would like to process the signal $I(x,y)$ in such a way that $L_R'(x,y)$, $L_B'(x,y)$, $L_G'(x,y)$, or $L_{BW}'(x,y)$ will allow the viewer a maximum discrimination of the luminance values $L(x,y)$ at each point, without substantial degradation of the spatial resolution. We first examine mapping which provides both a maximum number of distinguishable levels and a linear subjective scale. Among these, we consider in turn a mapping of grey scale into a grey scale image, a mapping of grey scale into a color image with constant brightness and controlled hue, and a mapping into a color image with controlled brightness and hue.

Mapping into a Grey Scale Image

It is well known that human vision adapts to an extremely large range of luminance levels, the extremes of which have a luminance ratio of more than one million to one [4,5]. However, the total range of luminance that the visual system can discriminate simultaneously is rather small and 15 to 20 grey scale steps from black-to-white are claimed as typical. This discrimination corresponds roughly to constant thresholds of $\frac{\Delta L}{L}$, a result which matches the commonly assumed logarithmic sensitivity of the eye to luminance values 4 . Thus, constant brightness steps will correspond to luminance steps spaced exponentially. Given a total range of luminance from black, L_B, to white, L_W, $L_R = L_W - L_B$, the relation

$$I_{BW}'(x,y) = [L_R + 1]^I + L_B - 1 \tag{1}$$

in which $0 \leq I \leq 1$, will yield the desired mapping in a subjective linear scale from black to white. It will also provide maximum visual discrimination in the quantity I. In the viewing of a CRT display, the available adjustment of brightness and contrast will take care of the adjustment to L_R and L_B and the signal processing has only to provide an exponential correspondence between I and I'. We found, experimentally, that a power law rather than an exponential law matches more closely properties of the human visual system. Differences may not be significant. These new results will be discussed quantitatively in a subsequent revision of this appendix.

Mapping into a Constant Luminance Pseudocolor Scale

To discuss color quantities, we shall make use of the CIE International XYZ Chromaticity System [1,3]. Such a diagram, with an indication of color regions, and with the locus of monochromatic light (wavelength in millimicrons) is shown in Figure A-3.

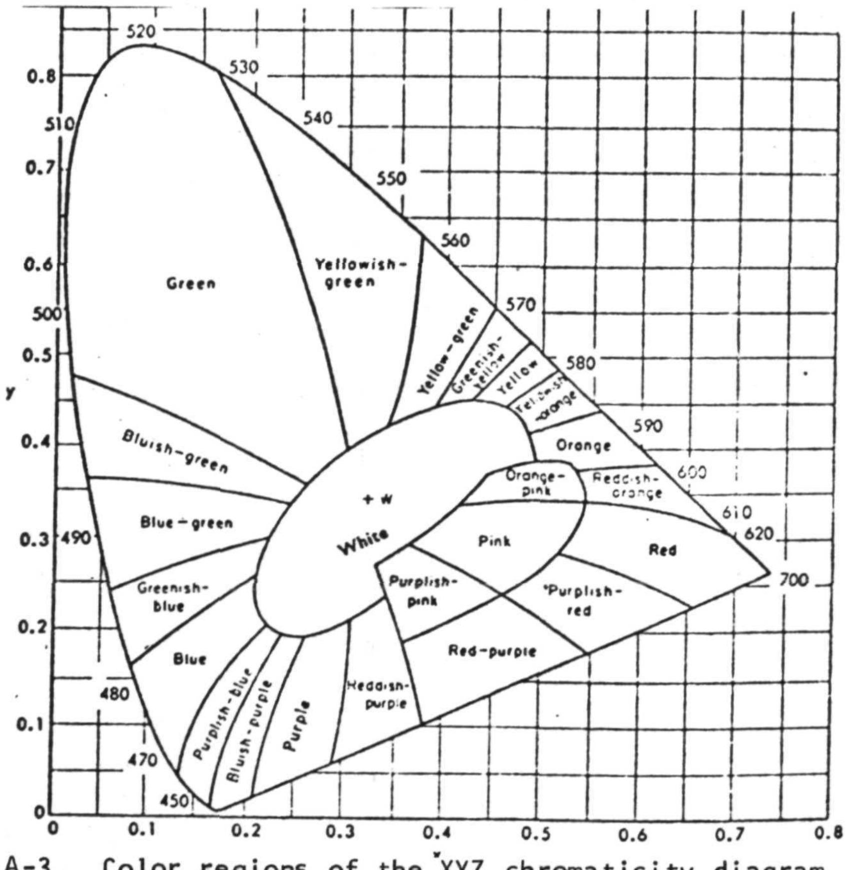


Figure A-3. Color regions of the XYZ chromaticity diagram.

The use of the color triangle allows the computation of the color resulting from the additive mixing of primary colors. Let, for instance, C_1 (x_1, y_1) and C_2 $(x_2 y_1)$ be two color positions on the color triangle and let C_3 represent a mixture of m_1 units (photometric or luminance) of C_1 and m_2 units of C_2. Then C_3 lies on the line joining C_1 and C_2 and is the center of gravity of $\frac{m_1}{y_1}$ placed at C_1 and $\frac{m_1}{y_2}$ placed at C_2 (center of gravity law). We shall use for our 3 primaries the coordinates

Red :	x = 0,675 ,	y = 0,325
Green:	x = 0,285 ,	y = 0,595
Blue :	x = 0,154 ,	y = 0,068

Thus, for any prescribed mixture of the three primaries which map a grey scale into pseudocolor, we follow a locus in the xy plane. From the laws of mixing this locus has to be inside the triangle defined by the coordinate of the primaries.

As an example of pseudocolor mapping at constant luminance, we consider the simple correspondence between the intensity value I and color indicated by the diagram of Figure A-4.

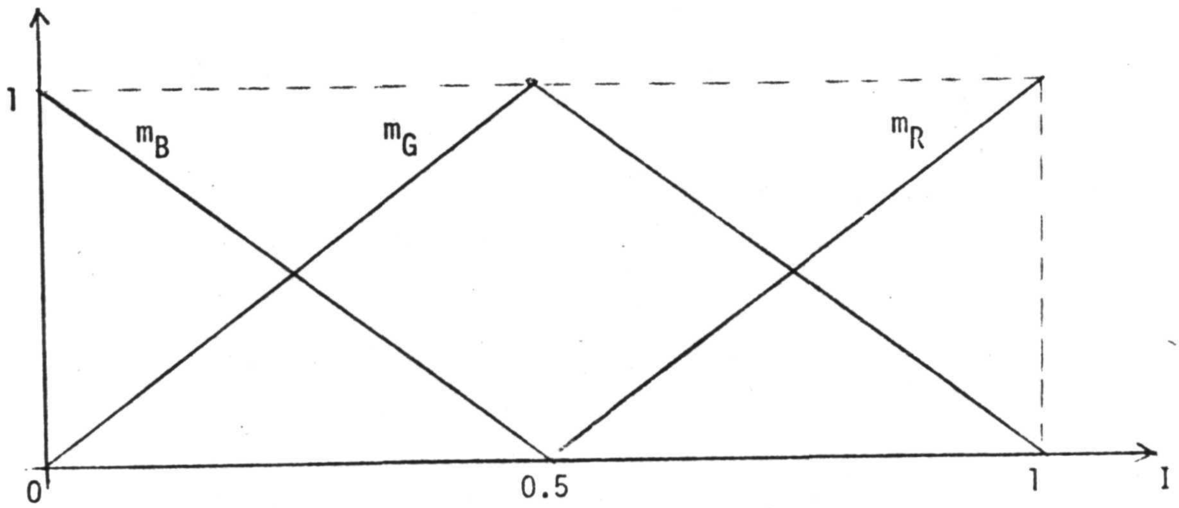


Figure A-4. Diagrammatic representation of the correspondence between intensity and color, as discussed in the text.

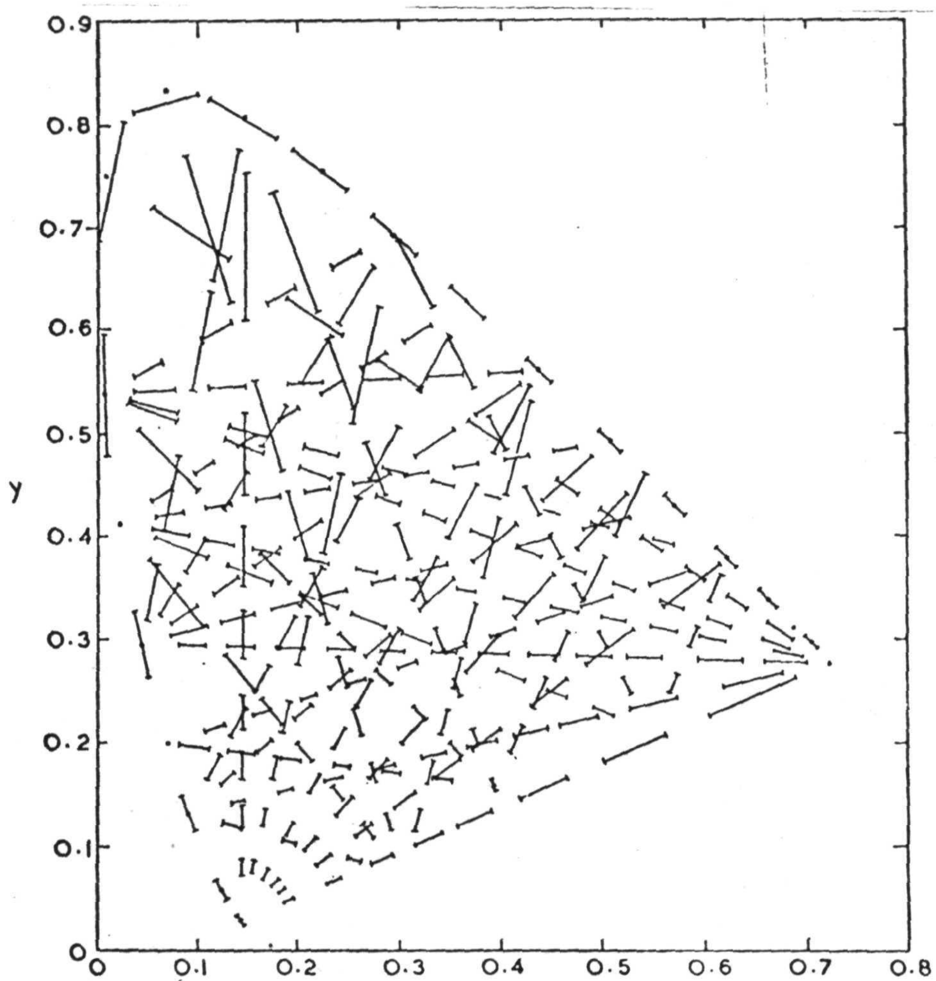
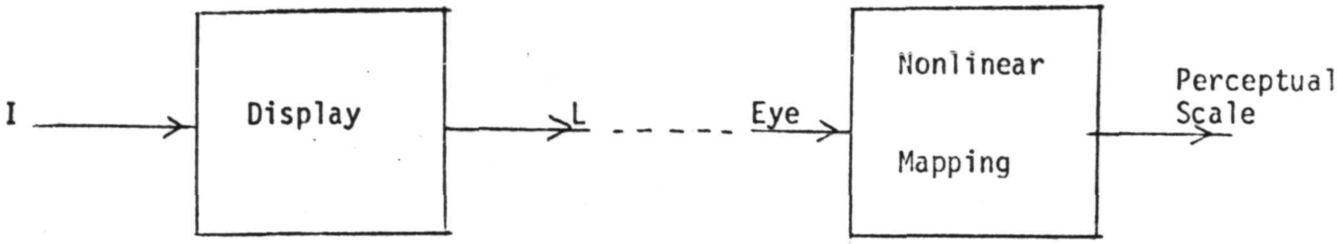


Figure A-5. Visually equal chromaticity steps at constant luminance on the C.I. E. x,y triangle

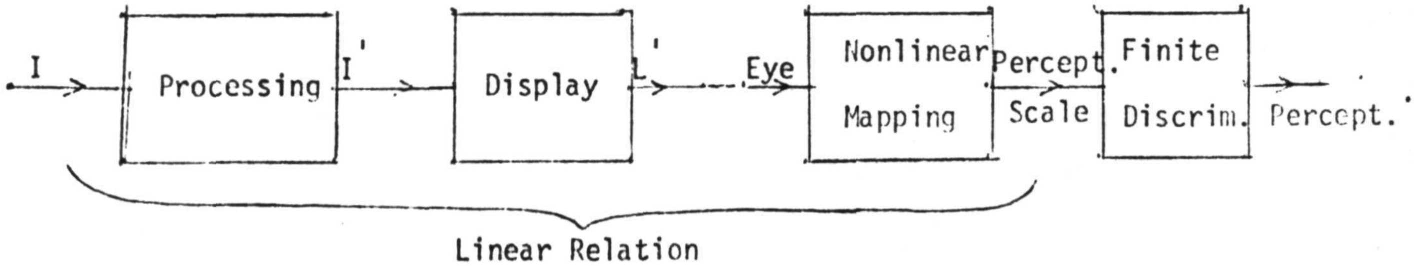
In this diagram, we only mix colors two at a time and remain on the edge of the triangle defined by the primaries. This choice provides a readily identifiable correspondence of grey scale values to hues and provides the maximum saturation for the colors. Other "conventional" mappings have been proposed [6]. As we generate our scale by mixing primary colors, we move along two line segments according to the center of gravity law. But since the ordinates y of primaries are quite different, the length of arc is covered at a quite nonuniform rate. Further, Figure A-3 labels regions of identified hue but does not imply that an observer perceives these hues as equidistant. Visually equal chromaticity steps have been established and are shown in Figure A-5. Thus, some interesting questions relate to the perceptual distance corresponding to the variation of I and its scale. Some answers can be determined by composing the results of the center of gravity law of mixing, with a perceptual distance as a function of arc length obtained graphically from Figure A-5. Perceptual distance as a function of arc length is shown in Figure A-6, and the perceptual distance as a function of I is shown in Figure A-7.* This last curve is quite nonlinear between the blue and the green but fairly linear between green and red.

Let us assume that we predistort the grey scale values T according to function which is the inverse of the curve of Figure 7, and we then

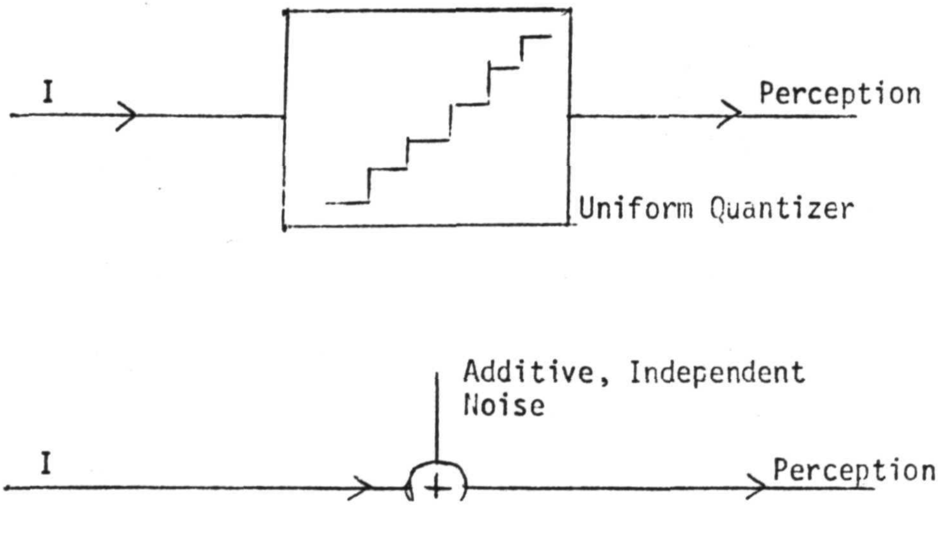
*Note that the use of the UV diagram yields approximate equiperceptual steps. Since in the UV diagram mixing follows the center of gravity law, the new effect of perceptual distance as a function of I is as shown in Fig. A-7.



a) Direct Display, No Processing



b) Linearization of Perceptual Scale



c) Models of Finite Discrimination

Figure A-11. Diagrammatic models to be considered in optimizing intensity distribution, as discussed in text.

apply the color generation scheme of Figure A-4. We have now a linear correspondence between the intensity variable I and a perceptual dimension. The important implication of this linearity is that, for the given mapping, it maximizes the number of distinguishable levels in the mapping. Other mappings, which may provide a longer total perceptual range can be linearized in the same way. One could conceivably look for a mapping which maximizes the perceptual range but such a mapping appears to lead to a confusing order of hues.*

Mapping with Variable Luminance and Color

The number of perceived distinct hues is very much larger than the number of perceived distinct grey scale values. Thus, it appears that there is little to gain in range discrimination by using a luminance variation as well as a variation in hue in the mapping. Although this is true for the mapping of images with low spatial detail, there is a significant argument for preserving luminance variations in high detail images. It is well known that the spatial acuity of human vision is rather poor for purely chromatic information. This property is used very successfully in broadcast color television, in which only 1/4 of the luminance bandwidth is provided for the chrominance signal.

To obtain maximum visibility of detail when mapping into a chrominance-luminance space, we would like to achieve a linear relation between the intensity variable I and the perceived brightness and hue.

---

*Note a similarity of this problem to the modulation and encoding problems in communication theory [11]. However, here the "demodulator" is the human observer and his capabilities are limited. See relevant discussion in Section A-6.

This perceptual distance has been studied extensively empirically [3]. As a first approximation, convenient to implement, we shall map grey scale values I into linear perceptual scales independently, on the brightness and hue coordinates as shown in Figure A-8.

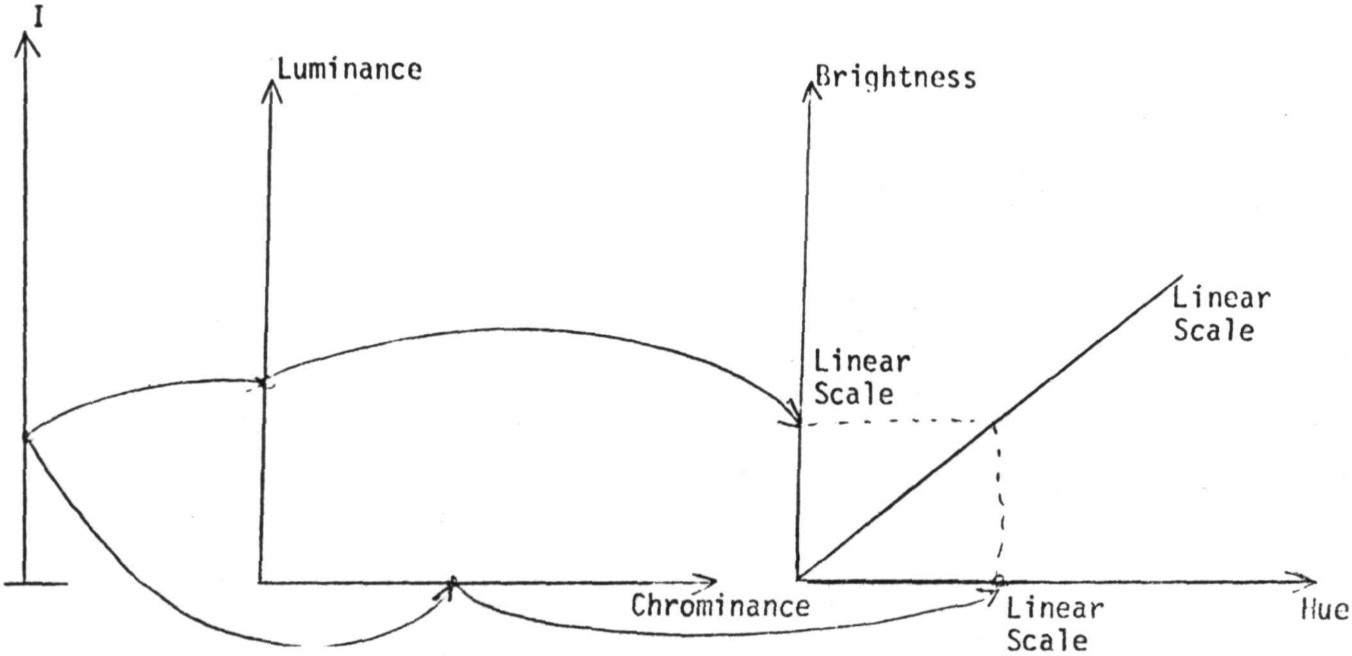


Figure A-8. The relationship between grey scale values, I, and linear perceptual scales of the brightness and hue coordinates.

Thus, from this mapping into a hue-brightness space we expect a slight improvement of differential perception of intensity values as compared to the same hue mapping at constant brightness. What should be improved significantly is the perception of spatial detail. Such a mapping may not be as pleasing aesthetically as mapping in uniformly bright hues, but these considerations do not enter into our study.

Experimental Determination of Differential Visibility

Although the precedent discussion is formally adequate, one is confronted, when applying these ideas experimentally, with the limitations of the display devices, the photographic process, etc. It is thus desirable to verify experimentally the differential sensitivity of each grey scale mapping. We have developed a single technique to perform this measurement which is specially suitable to interactive work, using a digital computer. The table of values shown in Figure A-9 is displayed using whatever grey scale mapping techniques and display devices are to be tested.

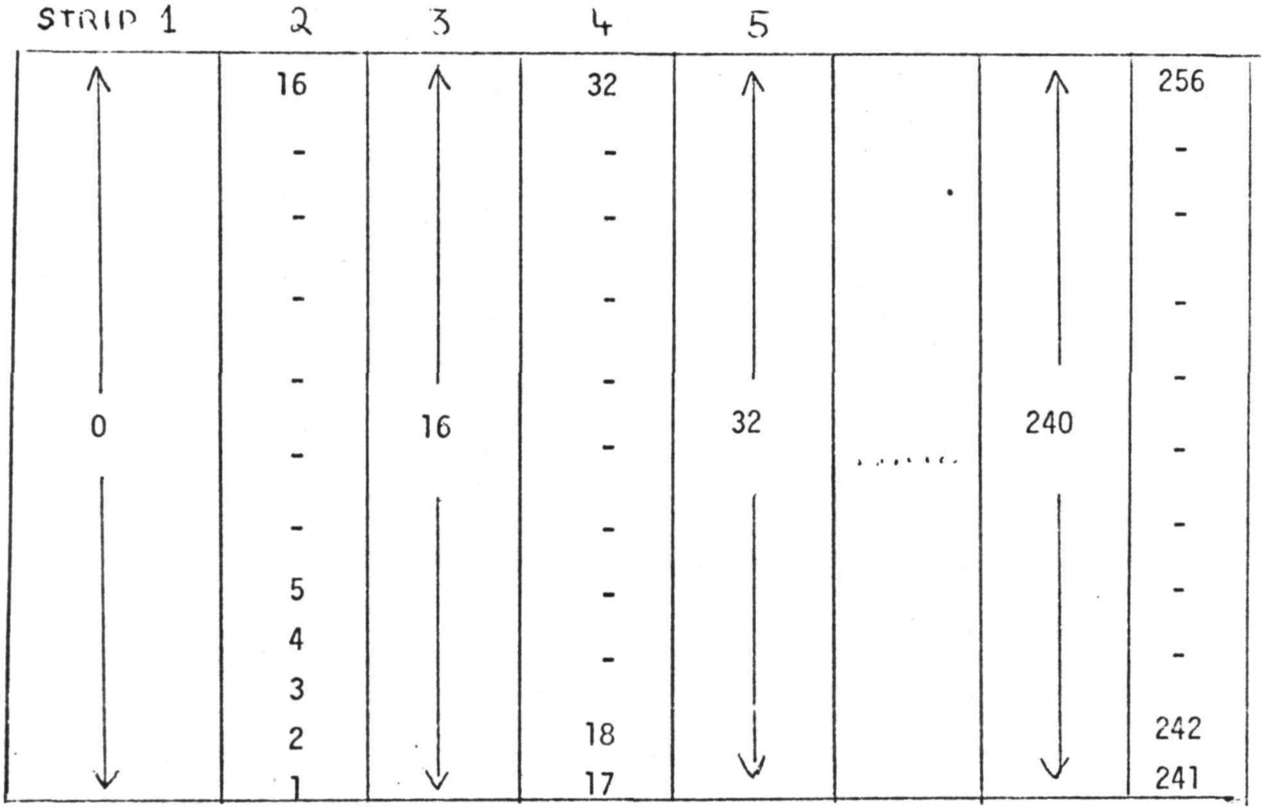


Figure A-9. Test image showing table of values used in an experimental determination of differential visibility.

The test table is designed so that the distance between adjacent strips is variable between 1 and 16. The total range 0 - 256 corresponds to the commonly used 8-bit integer display. A pseudocolor image of the test table is shown in Figure A-10. We observe the vertical lines of the test table but careful examination reveals that each line cannot be perceived vertically across the entire image. Assume that the line between strips 2 and 3 cannot be perceived for values of strip 2 between 8 and 9. That means that 16 - 8 = 8 is the threshold of visibility of the input variable for the proposed mapping in the range of input values 8 to 16. Thus by a single image one can verify the linearity of the scale and even devise a compensation table if needed. Work is not completed on this experimental phase and will be reported upon more fully later on.

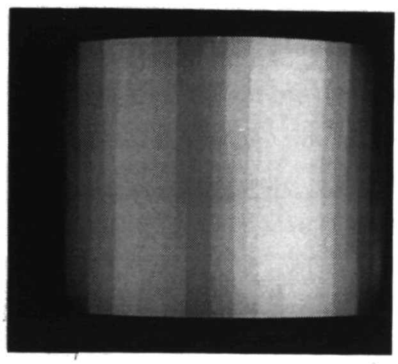


Figure A-10. A pseudocolor image of the tabular data shown in Figure A-9.

Mappings Based on the Statistics of Intensity Values

In our discussion of the mapping of intensity I into a linear perceptual space we have not made any assumption about the statistical distribution of I. It is clear, however, that some consideration of the distribution of I is needed, if for no other purpose than to scale the range of I so that the image enhanced covers the whole perceptual range

available. Considerably more can be said by combining the concept of perceptual space, with a constant differential, with some previous work on quantization and estimation of the author and others [8,9,10]. Assuming that we have still a limit on the increment ΔI which can be perceived, we can model this situation by assuming that the perceptual space is quantized, with uniform quantization steps, or by assuming that we have some additive noise which prevents the differential perception of small input increments. Figure A-11 illustrates the situation.

For both models of Figure A-11c, a precise mathematical optimization problem can be solved. Consider the model of Figure A-12.

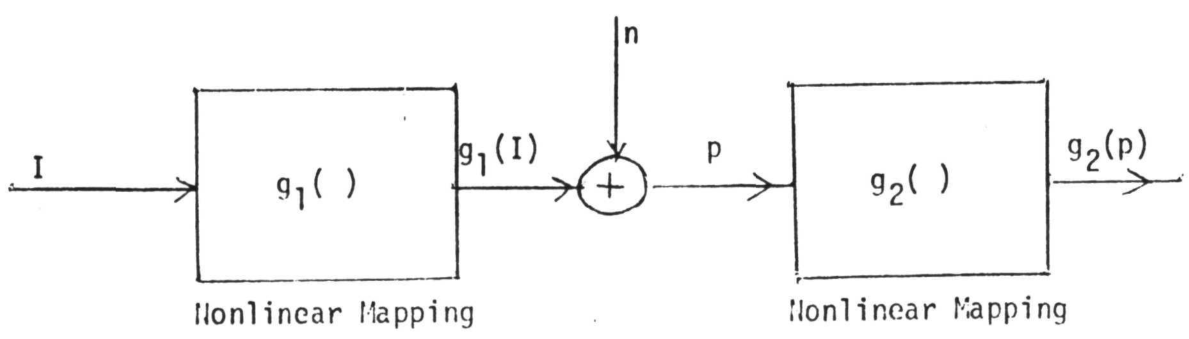


Figure A-12. Use of the concepts of Figure A-11 in solving a precise mathematical problem of optimizing intensity distributions.

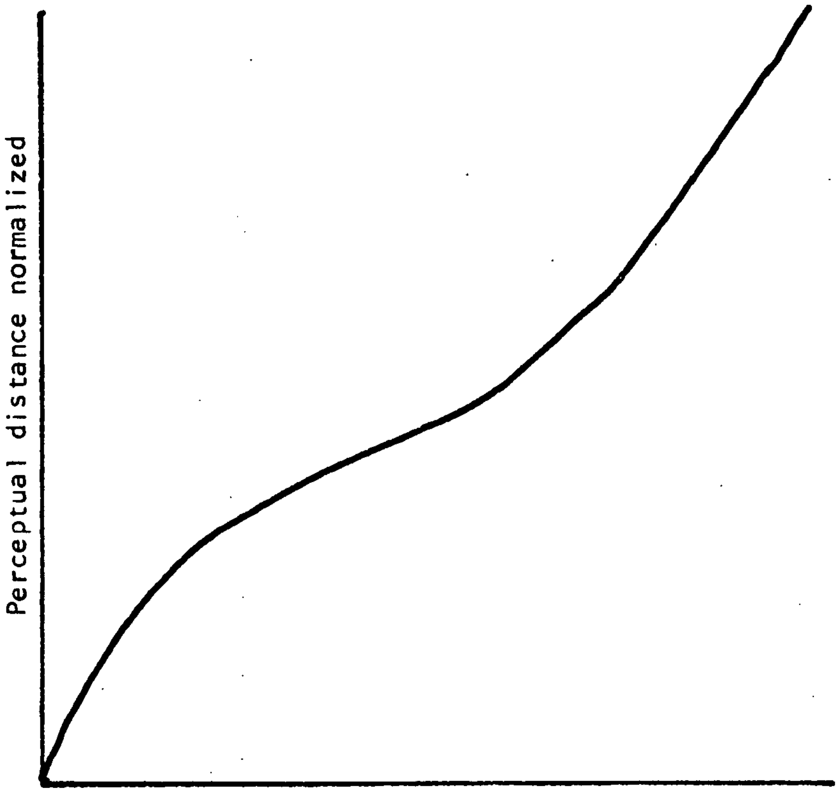

Perceptual distance normalized
Arc length on color triangle normalized.

Figure A-6.

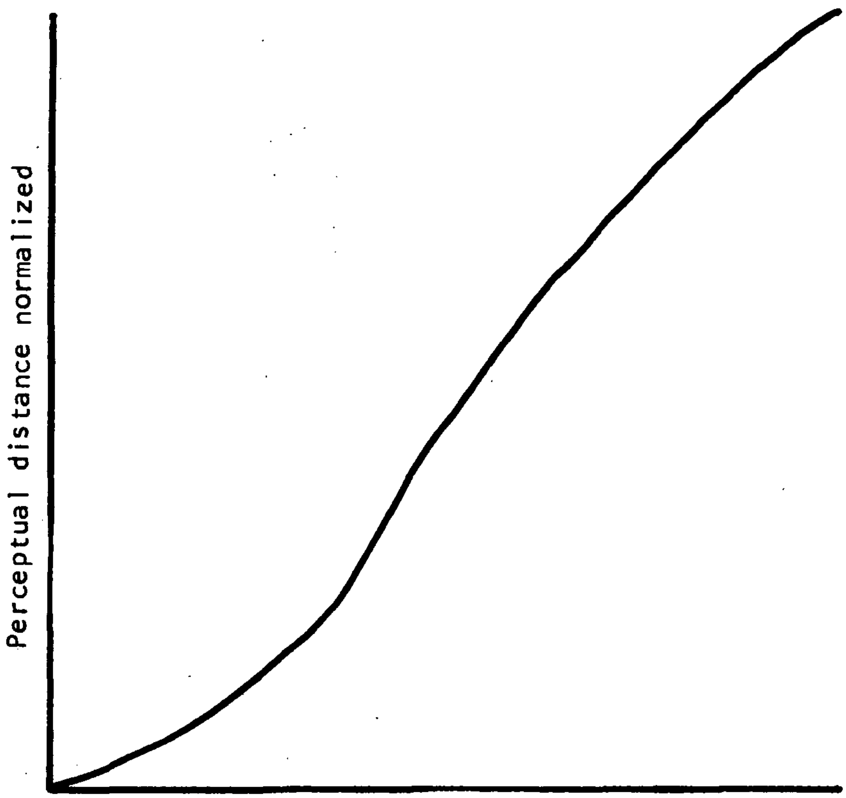


Figure A-7. Perceptual distance as a function of I.

We would like to determine the nonlinear mappings g_1, ( ) and g_2 ( ) such that the distortion D is minimized

$$D = E\{W[I - g_2(p)]\} \tag{2}$$

I - g(g) is the error between the input and output variables of Figure A-10, W( ) is an error weighting function, E denotes statistical expectation over the distribution of the random variable I. In a communication context, the optimization problem considered corresponds to the design of nonlinear scalar transmitters and receivers [10] If a uniform quantizer is substituted for the additive noise, we are then designing a nonuniform quantizer [9]. Under the conditions of small additive noise or small quantization steps the solution to both problems is the same.

Consider the class of error weighting function $W(e) = |e|^c$ and let us assume that the range of the variable $g_1(I)$ is limited. Then D of equation 2 is minimized by choosing

$$g_1(I) = K_1 \int_{-\infty}^{I} [f_I(x)]^{\frac{1}{c+1}} dx + K_2 \tag{3}$$

in which $f_I(x)$ is the probability density function of I and the constant K_1 and K_2 are chosen to yield the desired range for $g_1(I)$. For small noise $g_2(\ )$ is then the inverse of $g_1(\ )$. We have assumed in (3) that the range of I is limited and that $f_I(\ )$ does not have a long tail. For a discussion of the effects of the tails of $f_I(\ )$ see [9].

so that more frequent values are spread out farther in a perceptual scale. Thus, the mapping $g_1(\ )$ provides a global mapping from I to p with a nonlinear perceptual scale but which maximizes the total average visibility of the image.

Note that under the condition mentioned earlier $g_1(\ )$ does not depend on the specific number of quantization steps or additive noise in the model of Figure A-11c,and the results are applicable to all the mapping into a linear perceptual space discussed before.

A question remains open in the choice of constant c in equation 3. Recall that the class of error weighting function is $W(e) = |e|^c$. Since I is an intensity or energy variable, one would expect that c = 1 is a good choice. Note that the choice c = 0 has been proposed in an ad hoc manner [6].

Another result pertinent to image enhancement is available from Reference 9. It is possible to evaluate quantitatively the improvement in the visibility of the image due to the nonlinear mapping $g_1(\ )$ as a function of the probability density function $f_I(\ )$. If A and B are the limits of the range of $F_I(\ )$, then

$$F = \frac{D\ \text{Nonlinear}}{D\ \text{Linear}} = \frac{1}{[B-A]^c} \left[\int_A^B (f_I(x))^{\frac{1}{c+1}}\, d_x\right]^{c+1} \qquad (4)$$

We find F = 1 as expected if $f_I(\ )$ is uniform.

Applications

There are numerous fields of application for the techniques presented. We confine our discussion here to the enhancement of multispectral images. We shall enhance each spectral component independently as a grey scale

Let us now interpret and adapt these results to image enhancement. We can adapt the diagram of Figure A-12 to the case of vision as shown in Figure A-13.

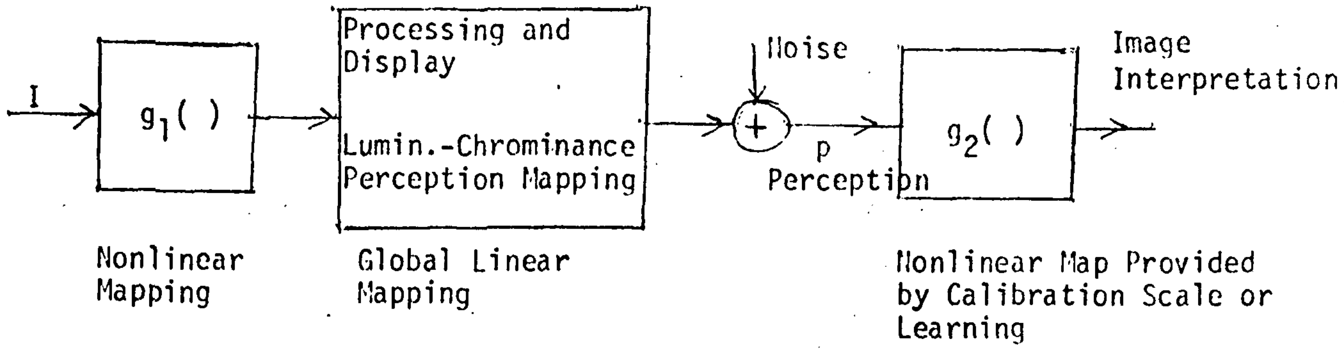


Figure A-13. Adaptation of Figure A-12 to the visual case.

The significant part of Figure A-13 is the interpretation of the non-linear operation $g_2(\ )$ as occurring in the brain and provided by learning. For instance, the display of a linear scale in I at the same time that the processed image is displayed allows the viewer to calibrate his visual scale and compensate for it. The compensation is indicated by $g_2(\ )$. What the introduction of the mapping $g_1(\ )$ has done is to reassign the intensity values I according to their frequency of occurrence

image. Since the spectral components are not statistically independent, this approach is not optimum and combined enhancement of 3 spectral components may have some advantages. However, independent processing of each spectral component is computationally extremely fast and interactive enhancement becomes possible. Note that enhancement using the statistics of the image is dependent on the area from which the enhancement mapping is generated. Thus, one can choose the features to be enhanced within an image. Note also that in remote sensing applications some ground truth is available and color is principally used for the discrimination and delineation of features. In such a situation, the knowledge of a calibrater scale for the colors displayed is not of great importance. Examples of applications of the enhancement technique are included in the body of the report. Note also that the characteristics of the photographic process have not been compensated for and that some improvement should be possible with compensation of film characteristics.

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Appendix 2

Enhancement of High Altitude Imagery to Emphasize Salt Patterns in the Earth

A. Samulon

An important application of high altitude photography to studies of earth resources is the determination of salinity concentration in soils of agricultural areas. The techniques of digital picture processing can be fruitfully applied to this problem. The use of high altitude imagery for salinity studies is being worked on by scientists at U.C. Davis (G. Huntington) in conjunction with the ERTS program, while in our group relevant digital processing techniques are being investigated. This progress report discusses the motivation and philosophy behind the digital work being done on this problem.

The Problem

Knowledge of the salinity condition of the soil is important in agricultural regions because of the restrictions salty soil puts on the type of crop that can be grown. In addition, the salinity of the soil in any particular location can vary over a period of several years. In irrigated areas, salinity is particularly variable because of irrigation's affect on the water table and the salinity of irrigation water itself. Since various measures can be taken to reduce the salt concentration in the soil or to prevent further increase, it is important that changes in soil salinity be detected.

The Value of High Altitude Synoptic Imagery

In order to detect changing salt conditions, regular monitoring is necessary. For several reasons high altitude photography is especially

suited to provide the soil scientist with raw data with which he can estimate soil salinity. These include the following:

1. Determination of dimensions of areas with high salt concentration to within a quarter of a mile or half a mile is sufficient for many purposes. This scale is well within the capability of such projects as ERTS or Skylab.

2. Saline soil reduces the vigor of plants growing in it. This reduction in vigor causes a decrease in reflectivity of the vegetation, particularly in the near infrared portion of the electromagnetic spectrum. Thus, contours of salt concentration in the earth tend to show up as contours in imagery taken of the earth from above. Consequently, high altitude imagery contains information pertinent to the detection of salt concentrations.

3. High altitude photography provides the soil scientist with synoptic views of large areas. This capability is valuable because knowledge of soil salinity is required for vast areas.

4. Satellite photography of the same area on the ground can be performed on a regular basis. This permits the soil scientist to observe changing patterns.

<u>The Soil Scientist's Approach to Photo Interpretation of Salt Concentration</u>

In general terms, the method used by soil scientists to analyze high altitude imagery consists of two steps. The first is the separation of patterns in images into two classes: those that can be called manmade (e.g., fields), and so-called nonmanmade patterns (e.g., contours caused by salt concentrations). In the second step, the nonmanmade patterns

are analyzed to see which ones indicate high soil salinity and which are due to other factors such as furrows made in bare soil by wind.

The problem of classifying nonmanmade patterns is a formidable one and is based on a great many factors. Among other things, the soil scientist must know something of the history and geology of the area represented in the image. At this time, digital data processing does not seem applicable to this step.

Application of Digital Processing

On the other hand, the first step in the analysis, the separation of manmade and nonmanmade patterns, is particularly suited to digital processing. In agricultural areas, the manmade patterns visible with high altitude synoptic photography are primarily fields. Depending on the crop in each field, the reflectance varies greatly from field to field. Any variations in reflectance due to nonmanmade features such as salt concentrations are superimposed on the reflectance due to the crops in the individual fields. The variations in reflectance due to the crops tends to obscure the nonmanmade patterns. By digital processing, we can emphasize the nonmanmade patterns and de-emphasize the manmade patterns. This enhancement should very much simplify the first step in the analysis of imagery and also be of value in the second step.

Substantial strides have been made toward the solution of the enhancement problem. A physical model of the relevant image properties and a corresponding mathematical representation have been developed and experimentally justified. A framework has been chosen by which

to determine the best processing method. Finally, preliminary image processing indicates that we are proceeding in the proper direction.

Physical Model

The physical model explains how the reflectivity at each point on earth is related to the manmade feature and the nonmanmade feature at that point. It further contains a number of assumptions about manmade patterns and nonmanmade patterns. Using these assumptions, a method can be derived for separating the patterns in an image. The main assumptions in the model are the following:

1. At the scale of synoptic high altitude photography, the primary manmade features visible in agricultural areas are fields.

2. Over any given field, the reflectivity would be a constant at the resolution available were it not for nonmanmade features underlying the field.

3. Boundaries of fields are straight lines. This assumption is valid for most agricultural areas of the United States outside the first thirteen states.

4. Nonmanmade features are not bounded by straight edges.

5. Soil salinity tends to be distributed with no preferred direction.

6. Soil salinity tends to vary gradually over areas of size comparable to that of a field.

7. Reflectance of a particular crop is proportional to the "vigor" of the crop. This should be interpreted as follows: consider two different plants. The ratio of the reflectivity of the two plants is constant as long as the vigor of the two plants is equal (i.e., it is independent of the actual vigor of the plants.) Preliminary experimentation indicates

this assumption is sufficiently good for the purpose of separating man-made and nonmanmade patterns.

Mathematical Representation

The mathematical model representation expresses the assumptions in a mathematical form. The image is viewed as a function, $f(x,y)$, from the two dimensional spatial domain into a range of grey levels. The assumption which relates the reflectivity to the manmade and nonmanmade features then can be expressed mathematically as

$$f(x,y) = g(x,y)e(x,y)$$

where g and e are nonnegative, g representing the manmade component of the picture and e the nonmanmade portion. Then

$$\log f(x,y) = \log g(x,y) + \log e(x,y)$$

Let $\phi(x,y) = \log f(x,y)$

$\gamma(x,y) = \log g(x,y)$

$\theta(x,y) = \log e(x,y)$

Then

$$\phi(x,y) = \gamma(x,y) + \theta(x,y)$$

We take as the object of the enhancement, estimation of $\theta(x,y)$ given $\phi(x,y)$. Our approach is to find the best (in the mean square sense) linear, spatially varying, noncausal filter, h, to apply to ϕ. That is, our estimate, $\hat{\theta}(x,y)$, is given by

$$\hat{\theta}(x,y) = \iint_{-\infty}^{\infty} h(x,y,\tau,\nu)\phi(\tau,\nu)\,d\tau\,d\nu$$

where h is chosen such that $E[\theta(x,y) - \hat{\theta}(x,y)]^2$ is minimized.

Conclusion

We have discussed the motivation behind a particular application of digital image enhancement. In addition, a model has been developed on which an enhancement method can be based. Preliminary experiments indicate that this approach will lead to a useful enhancement method. It is expected that by the next progress report enhanced images will be available.

Chapter 9

INVESTIGATION OF ATMOSPHERIC EFFECTS IN IMAGE TRANSFER

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9.1 INTRODUCTION

Progress on this part of the investigation has been mainly in three areas during the reporting period. First, measurements of the individual elements of the reflection matrix have been obtained for a number of natural materials. As far as is known, the individual elements have not been measured previously. The second area of progress has been in instrumentation. The computer-controlled polarizing radiometer being developed for measurements on this project is now completely automated, and is applicable for measurements of either the reflection properties of surfaces or the distribution of intensity and polarization of light from the sunlit sky. As is well known, the characteristics of skylight are indicators of atmospheric turbidity, a subject of importance in remote sensing applications. Thirdly, considerable thought has been given to a new type of instrument for sensing and display of information on the polarization of light as a means of distinguishing among various types of agricultural and urban surfaces from a satellite or other remotely located platform. Finally, modest progress has been made on the parameterization of the reflection of light from natural surfaces, in terms of their physical characteristics of roughness and specular reflection properties. All of these subjects will be discussed in more detail below. No major problems in the work

have been encountered during the period, although progress on the atmospheric aspects have not progressed as rapidly as had been anticipated. The delay was occasioned by the absence of the meteorologist of the group (Professor Coulson), who was on sabbatical leave during the period September 1, 1971 to August 31, 1972. He is back on campus now, however, and increased progress in atmospheric investigations is anticipated.

9.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

9.2.1 Measurements of the Reflection Matrix

The reflection properties of natural surfaces are of importance in many studies dealing with problems of the environment: discrimination among surfaces of various types, evaluation of the effects of background light on contrast transmission through the atmosphere, the role of surface reflection in the energy budget of the atmosphere.

Until the advent of the space program, interest in the reflection properties of natural surfaces received relatively little attention. The light reflected from geographical areas was used, of course, in aerial photographs of the areas, but the main interest was in the delineation of relatively obvious features of the landscape. The requirements for such purposes were comparatively undemanding. However, during the last decade or so astronomers and others interested in surface properties of Mars, and particularly of the moon, have endeavored to simulate those surfaces by earth-borne materials. Although some erroneous conclusions were drawn from the results, our knowledge of the reflection of light by various (mainly mineral) materials has been greatly enhanced by the studies.

Emphasis in the simulation studies, as well as in studies of remote

sensing, has, with a very few exceptions, been on the intensity of the reflected light, as a function of wavelength, angle of incidence, and angle at which the surface is viewed. Little attention has been given to the additional information contained in the state of polarization of the radiation stream. In principle, however, more information may be contained in the field of polarization than in the intensity field, and the polarization field is also dependent on wavelength and geometrical parameters. Thus, by simultaneous measurements of both the intensity and state of polarization, the most powerful tool for extracting information from a field of radiation is obtained. This is the basis for the present study to determine as completedly as possible the reflection properties of natural surfaces.

If we represent the Stokes parameters of the light of wavelength incident on a surface from zenith angle θ' and azimuth ϕ' by the vector

$$I' (\lambda; \theta', \phi') = \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} \tag{1}$$

and that reflected into direction (θ, ϕ) by

$$I (\lambda; \theta, \phi) = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} \tag{2}$$

then the reflection matrix by which the surface properties may be characterized is defined by the relation

$$I\ (\lambda;\ \theta,\ \phi) = R\ (\lambda;\ \theta,\ Q,\ \theta',\ \phi')\ \ I\ (\lambda;\ \theta',\ \phi') \qquad (3)$$

or, on expansion, the complete reflection matrix takes the form

$$\begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} \quad \begin{bmatrix} M_{II} & M_{IQ} & M_{IU} & M_{IV} \\ M_{QI} & M_{QQ} & M_{QU} & M_{QV} \\ M_{UI} & M_{UQ} & M_{UU} & M_{UV} \\ M_{VI} & M_{VQ} & M_{VU} & M_{VV} \end{bmatrix} \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} \qquad (4)$$

It is of interest to note that the scalar intensity, the quantity normally used in remote sensing, is given in terms of the single matrix element M_{II} by the scalar equation

$$I = M_{II}\ I' \qquad (5)$$

This means that the other elements of the matrix are not utilized in the normal methods of remote sensing.

For practical purposes, a significant simplication of Equation (4) is possible. Observations show that for natural sunlight, the ellipticity V' of the incident light is vanishingly small. This means that the reflected light carries no information on the four matrix elements, M_{IV}, M_{QV}, M_{UV}, and M_{VV}. These elements may well be valuable for characterizing a reflecting surface in the laboratory, but they are not observable under natural sunlit conditions. Thus we will neglect them in the present discussion.

This leaves twelve of the sixteen elements still available for surface characterization in sunlit conditions, and there is no a priori reason to think one is more useful for the purpose than any other. In the

measurements performed so far on this project, concentration has been on measuring the field of linear polarization of the reflected light, a procedure that yields data on nine of the remaining twelve elements. The other three elements, M_{VI}, M_{VQ}, and M_{VU}, require measurements of the ellipticity of the reflected light, and, while the polarimeter being used has the capability of measuring ellipticity, an additional set of measurements is required. Insufficient time for them has been available so far, but it is anticipated that they will be made during the next period of the study.

A large number of measurements of the scalar intensity I (θ,Q), degree of plane polarization P (θ,Q), and angle χ (θ,Q) of the plane of polarization of the reflected light have been made in the laboratory for different states of polarization of the incident light and for a number of different types of surfaces. Before showing the results of the measurements, it is well to look at the method of extracting values of the individual matrix elements from the three quantities measured. The incident light was rendered completely polarized by placing a polarizer in front of the aperture of the source. If the plant of polarization of this incident light, taken with respect to the plane of incidence is η, then we have the following conditions

$$\begin{aligned}
&\text{For } \eta = 0, && Q'_o = I'_o, && U'_o = 0 \\
&\text{For } \eta = 45^\circ, && Q'_{45} = 0, && U'_{45} = I'_{45} \\
&\text{For } \eta = 90^\circ, && Q'_{90} = I'_{90}, && U'_{90} = 0 \\
&\text{For } \eta = 135^\circ, && Q'_{135} = 0, && U'_{135} = -I'_{135}
\end{aligned} \tag{6}$$

By performing the algebra indicated in Equation (4) we obtain the relations

$$
\begin{aligned}
I_n &= M_{II}\, I'_n + M_{Q}\, Q'_n + M_{IU}\, U'_n \\
Q_n &= M_{QI}\, I'_n + M_{QQ}\, Q'_n + M_{QU}\, U'_n \\
U_n &= M_{UI}\, I'_n + M_{UQ}\, Q'_n + M_{UU}\, U'_n
\end{aligned}
\tag{7}
$$

by which the individual matrix elements can be determined.

From the definition of the Stokes parameters we have

$$
\begin{aligned}
Q &= I\ P\ \mathrm{Cos}\ 2\chi \\
U &= I\ P\ \sin\ 2\chi
\end{aligned}
\tag{8}
$$

where the degree of polarization P and angle of the plane of polarization χ are determined by the measurements.

By substituting appropriate values from Equation (7), it is easy to obtain the following relations in which the meausrements are used to compute the nine matrix elements. It is assumed that the incident intensity I' is independent of its plane of polarization; i.e.,

$$I'_o = I'_{90} = I' = I' \tag{9}$$

The individual elements are determined explicitly by the following relations:

$$M_{II} = \frac{I_o + I_{90}}{2\ I'} = \frac{I_{45} + I_{135}}{2\ I'}$$

$$M_{IQ} = \frac{I_o - I_{90}}{2\ I'}$$

$$M_{IU} = \frac{I_{45} - I_{135}}{2\ I'}$$

$$M_{QI} = \frac{I_o\, P_o\, \mathrm{Cos}\ 2\,\chi_o + I_{90}\, P_{90}\, \cos\ 2\,\chi_{90}}{2\ I'}$$

$$M_{QQ} = \frac{I_o P_o \cos 2\chi_o - I_{90} P_{90} \cos 2\chi_{90}}{2I'}$$

$$M_{QU} = \frac{I_{45} P_{45} \cos 2\chi_{45} - I_{135} P_{135} \cos 2\chi_{135}}{2I'} \tag{10}$$

$$M_{UI} = \frac{I_{45} P_{45} \sin 2\chi_{45} + I_{135} P_{135} \sin 2\chi_{135}}{2I'}$$

$$M_{UQ} = \frac{I_o P_o \sin 2\chi_o - I_{90} P_{90} \sin 2\chi_{90}}{2I'}$$

$$M_{UU} = \frac{I_{45} P_{45} \sin 2\chi_{45} - I_{135} P_{135} \sin 2\chi_{135}}{2I'}$$

Thus all of the elements can be determined by measurements with the incident light plane polarized and the plane of polarization oriented at four different angles.

This method has been used for measurements on six different types of surfaces (volcanic cinders, Yolo loam soil, white gypsum sand, desert sand, a green leaf, dry leaves) during the reporting period. So far the measurements have been confined mainly to the principal plane, and have been mainly at a wavelength of 0.7 μm. An extension to other angles and wavelengths is a part of the work anticipated for the next period.

In order to obtain the extremes of surface characteristics likely to be encountered, one very dark surface and one very light surface were selected for measurements. The dark surface is composed of black-colored volcanic cinders obtained from the top of Mt. Haleakala on the island of Maui, Hawaii. The cinders are irregularly shaped particles from a few

millimeters to a centimeter in dimension. The surface composed of the cinders has a coarse texture and contains large numbers of interstices for the trapping of light among the particles.

A sample of white gypsum sand from the White Sands area of New Mexico was chosen as the light surface. The particles of sand are relatively uniform in size, measuring generally less than a half millimeter in diameter. The individual grains are translucent in appearance. The surface has a typical sandy texture, and is yellowish white in color. Data for these two extremes of surface type, as well as for more usual types of materials, are shown below.

Values of the matrix elements determined from measurements for volcanic cinders are shown in the nine sections of Figure 9.1 The four curves in each are four different zenith angles θ_o of the source ($\theta_o = 0^o, 20^o, 40^o, 60^o$). Element M_{II} is the same quantity as the bidirectional reflectance discussed by many authors. For this very dark surface M_{II} has low values for all angles of incidence and at all angles at which the surface is viewed. There is an indication of a peak in the exact backward direction, but mechanical interference between source and polarimeter prevents measurements at that particular angle. Such a maximum has been observed previously, and it appears to be due to the fact that the instrument sees less of the shadow cast by roughness elements of the surface for the case of exact coincidence of source and observation angles than in any other conditions. The effect is most pronounced for dark colored surfaces, because the shadows are most intense in that case, and the lengthening of the shadows with increasing source angle makes the effect most pronounced

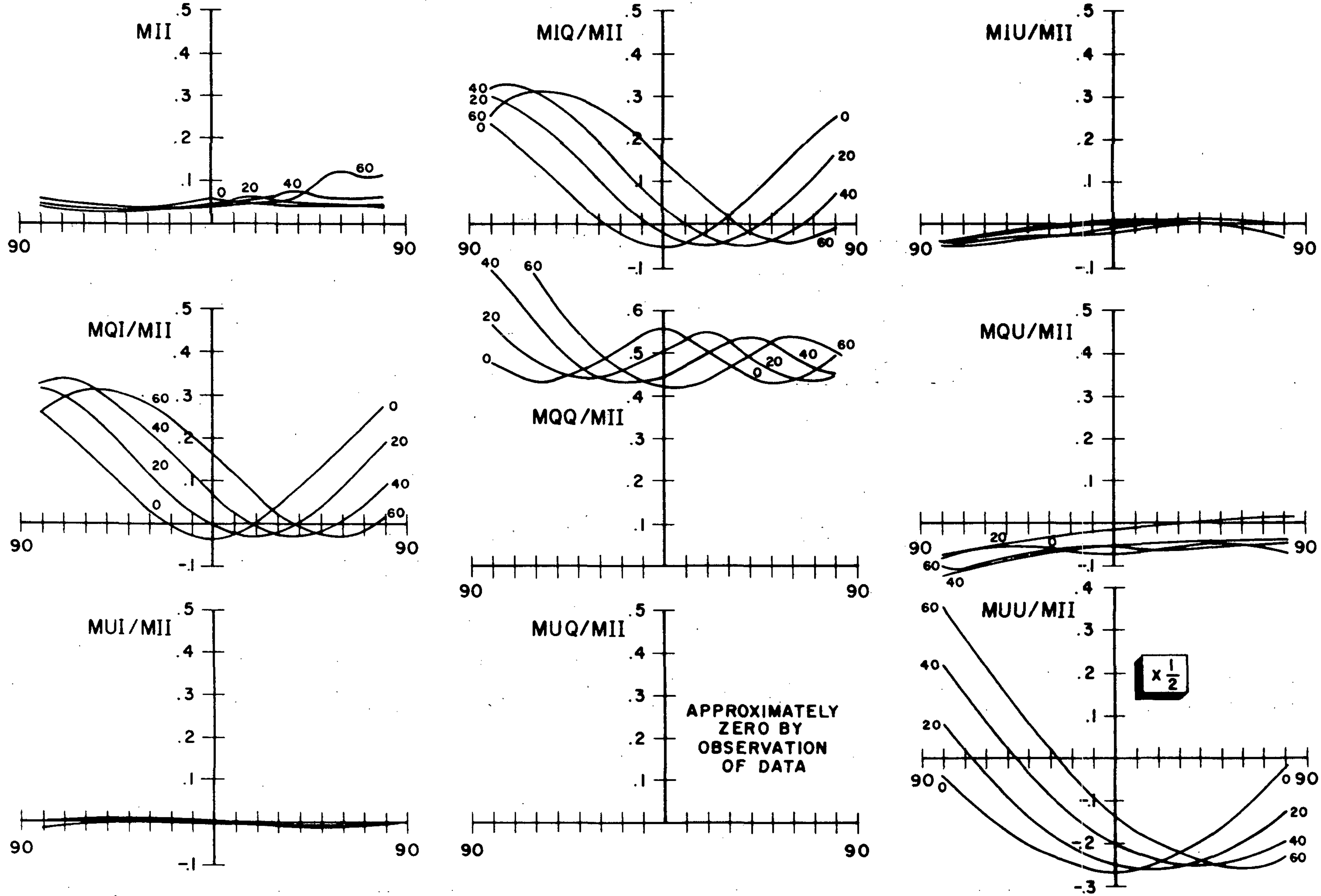

Figure 9.1. Measured values of the normalized elements of the reflection matrix for volcanic cinders, as a function of angle in the principal plane, for four different angles of incidence. (θ_o = 0, 20, 40, 60°, λ = 0.70 μm)

at the largest angles of incidence.

It is convenient for plotting purposes to normalize the other elements to that of M_{II}. For this case of the principal plane, Stokes parameter U is identically zero (because of symmetry considerations), and the ratio M_{QI} / M_{II} gives the degree of plane polarization of the reflected light. The curves show that polarization reaches values of more than 30 percent, which is higher than that for more highly reflecting surfaces. This is a manifestation of the "Omov effect," named after the Russian physicist of the early twentieth century who observed that materials which reflect strongly show low polarization, and vice versa. The neutral points are well defined at about 20^{o} above and below the position of the source. The shape of the curves is almost independent of angle of incidence, the controlling parameter being the phase angle $\theta - \theta_{o}$ between angles of incidence and reflectance. This feature will be discussed further below.

The ratio M_{UI} / M_{II} is the Stokes parameter U, and for this case of the principal plane it appears, within the error of measurement, to be identically zero as would be expected. The physical significance of the other elements is not so simple as for M_{II}, M_{QI}, and M_{UI}. In fact, as far as is known, no attempt has been made to obtain a physical interpretation of them. Thus only a descriptive discussion can be provided.

Other elements which are very small or identically zero, within measurement error, are M_{UQ} and perhaps M_{II}. Element M_{IQ} is almost identical to element M_{QI} for this case of the principal plane. It will be interesting to see if the identity holds also at other azimuths. Element M_{UU} has a large magnitude with well pronounced "neutral" points, whereas M_{QQ} is

large but always positive. In these cases also, the phase angle is the controlling parameter. Finally, element M_{IU} appears to be small in magnitude and of mostly negative sign.

Equivalent curves of the matrix elements for white gypsum sand are shown in Figure 9.2. Elements which were small for volcanic cinders (M_{UI}, M_{UQ}, M_{IU}) are small also for white sand. The high reflectance is manifested by a large value of M_{II}, and the Omov effect in operation gives small values of M_{QI} (degree of polarization). The other elements are generally smaller than for the case of volcanic cinders, but they appear to be well defined. The phase angle is obviously the dominant parameter in several of the elements.

Data for surfaces of more practical interest in problems of remote sensing are shown in Figures 9.3-9.6. There is considerable variation among the elements and combinations of elements for the various materials. These variations, of course, are the means for discrimination among the types of surfaces, and their further definition is a main objective of the continuing study.

One word is in order on the configuration of the curves in the backward direction for some of the elements, where interference between source and polarimeter prevents measurements. In most cases, the curves have been drawn to indicate a slight maximum in the region. It is considered more likely, however, that the maxima of, for example, elements M_{II} and M_{QQ} are quite pronounced, as indicated in the case of Yolo loam. This is a point for further clarification by additional measurements.

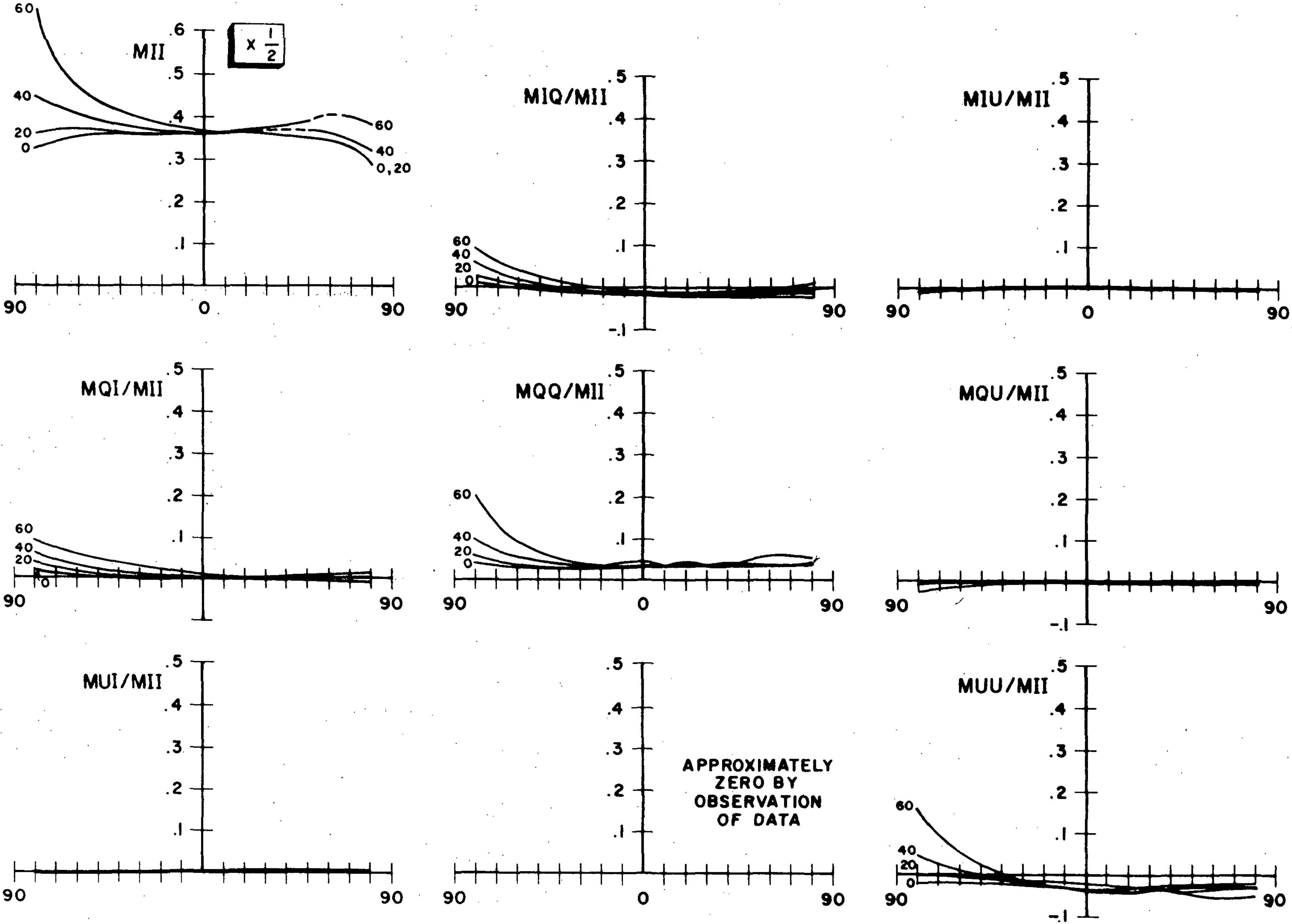

Figure 9.2. Measured values of the normalized elements of the reflection matrix for white gypsum sand, as a function of angle in the principal plane, for four different angles of incidence. (θ_o = 0, 20, 40, 60^o, λ = 0.70 μm)

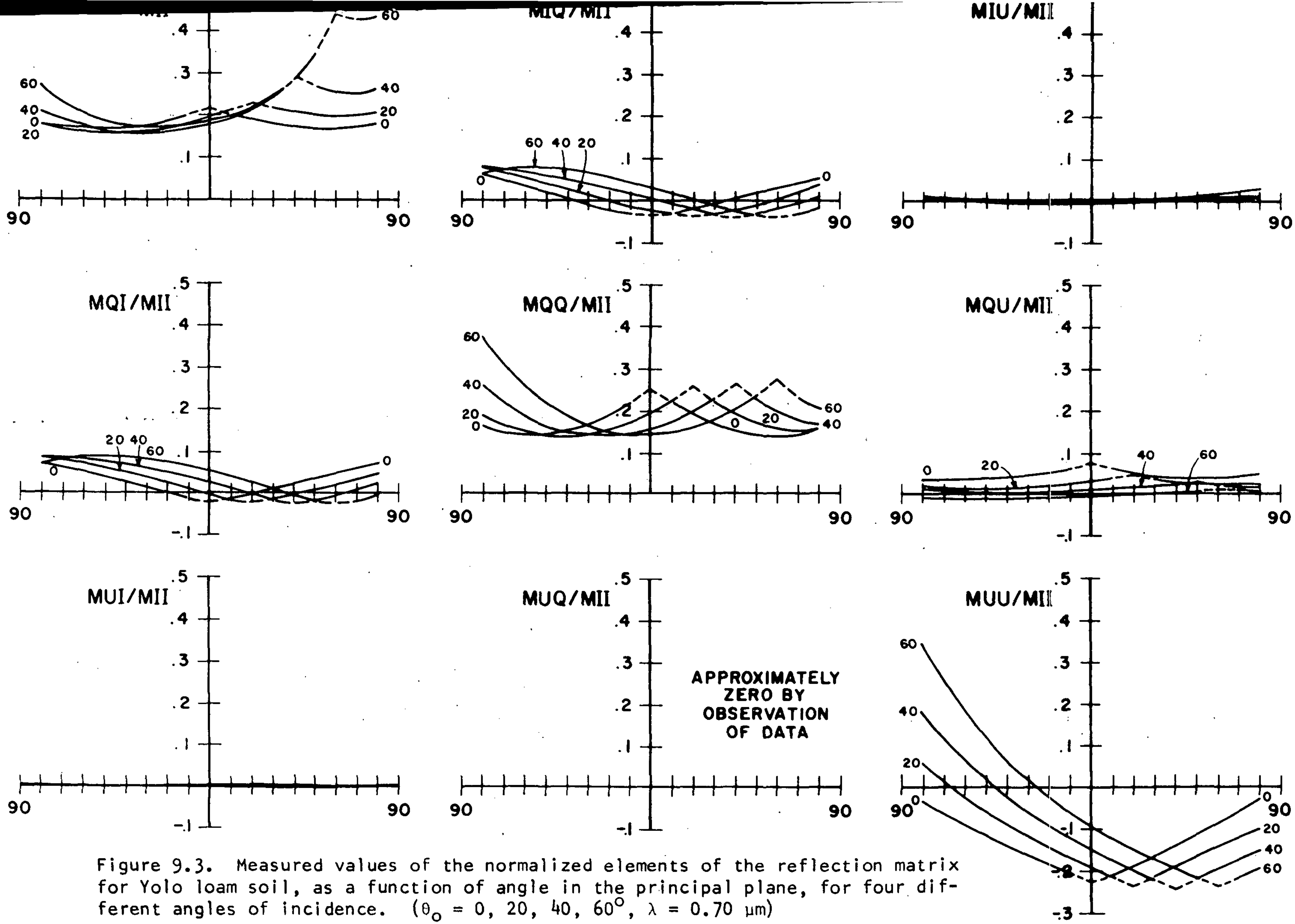

Figure 9.3. Measured values of the normalized elements of the reflection matrix for Yolo loam soil, as a function of angle in the principal plane, for four different angles of incidence. (θ_o = 0, 20, 40, 60°, λ = 0.70 μm)

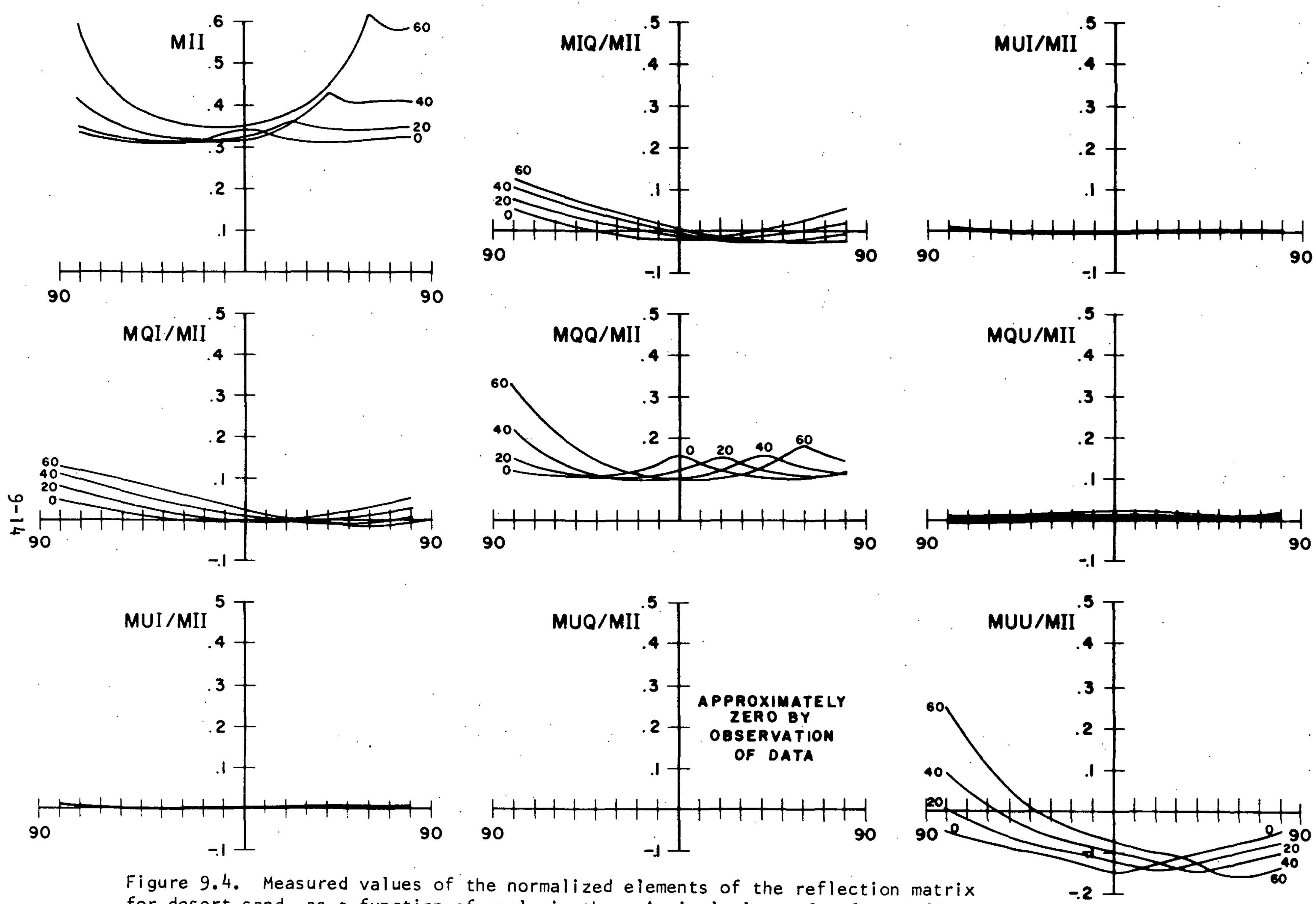

Figure 9.4. Measured values of the normalized elements of the reflection matrix for desert sand, as a function of angle in the principal plane, for four different angles of incidence. (θ_o = 0, 20, 40, 60°, λ = 0.70 μm)

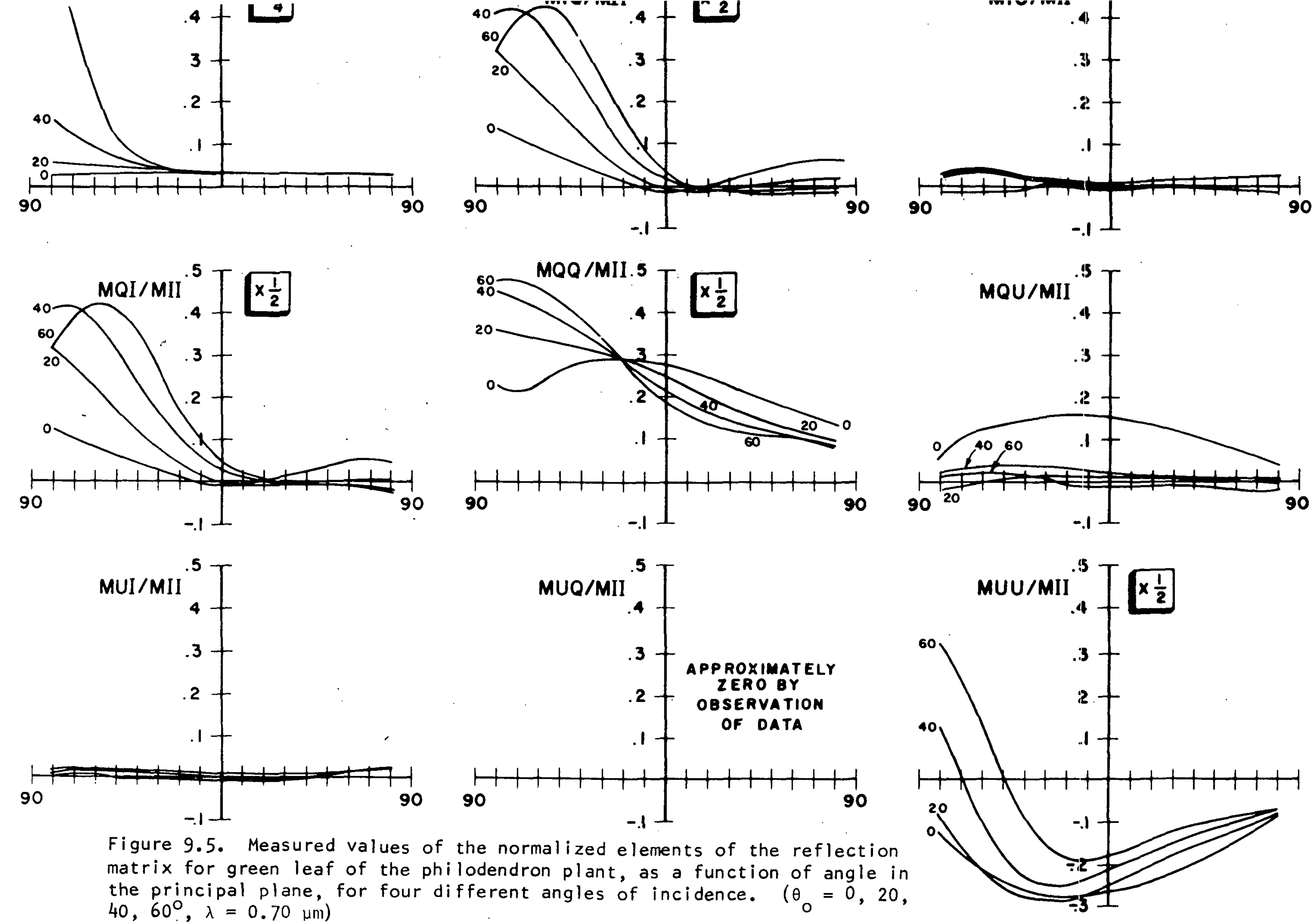

Figure 9.5. Measured values of the normalized elements of the reflection matrix for green leaf of the philodendron plant, as a function of angle in the principal plane, for four different angles of incidence. (θ_o = 0, 20, 40, 60°, λ = 0.70 μm)

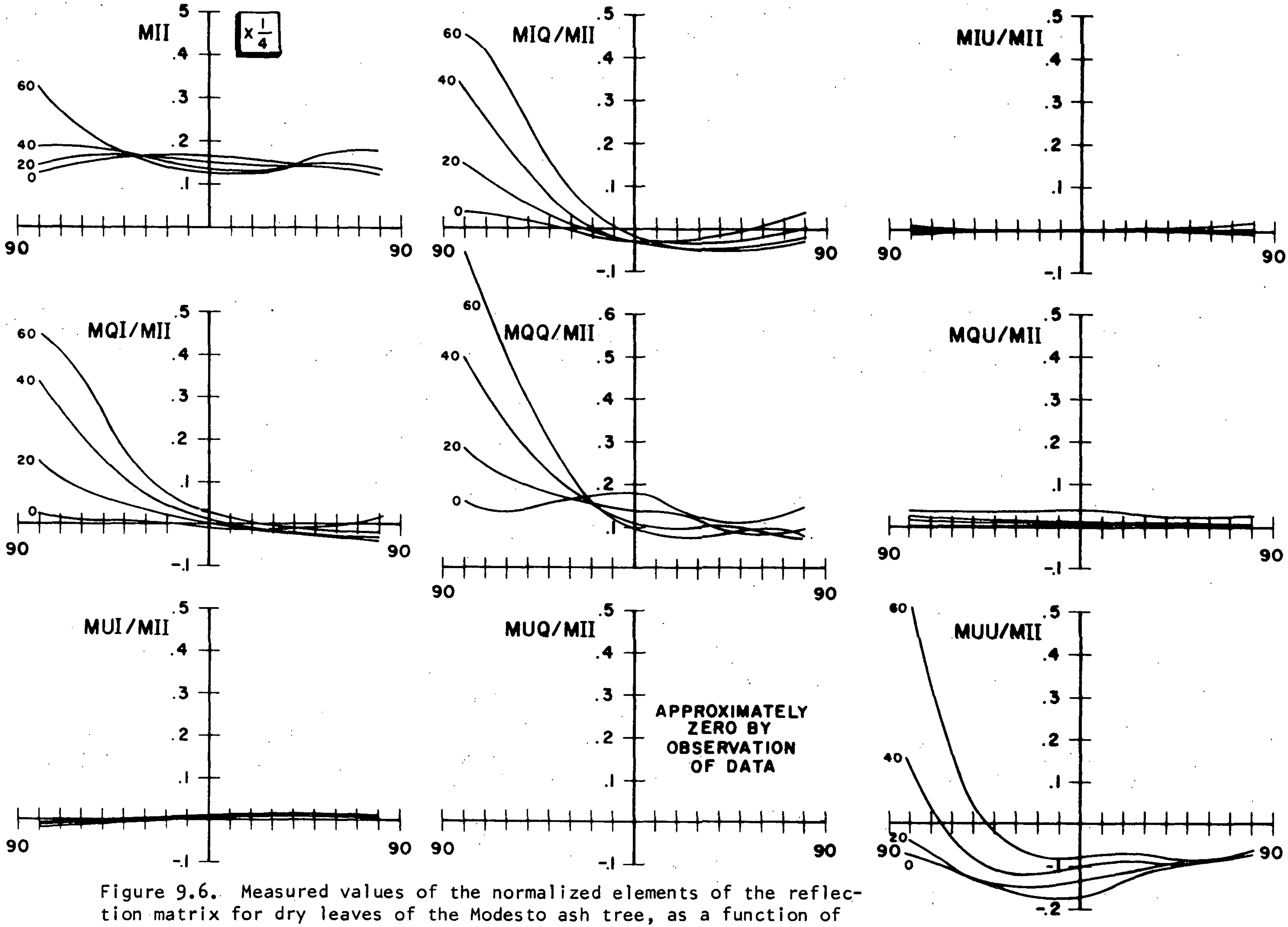

Figure 9.6. Measured values of the normalized elements of the reflection matrix for dry leaves of the Modesto ash tree, as a function of angle in the principal plane, for four different angles of incidence. (θ_o = 0, 20, 40, 60°, λ = 0.70 μm)

9.2.2 Parameterization of the Matrix Elements

Because of the large number of data required to characterize a surface by its reflection matrix, and the variations of the matrices with wavelength to be expected, it is very desirable to find a method by which as much of the information as possible can be represented in terms of a few parameters. The initial steps to find the best type of parameterization have been taken during the period. Although the results are extremely preliminary, they appear promising.

There are two methods of approach to such parameterization. The most desirable is to express the parameters in terms of the relevant physical quantities -- wavelength of radiation, size of surface roughness elements, etc. Some progress has been made in this direction during the period, but the results are not sufficiently advanced to report as yet. The easier method of parameterization is to take a purely empirical approach, representing the character of the curves by a small number of parameters which are not expressed in a direct fashion by the physical quantitites. Somewhat more progress has been made in this direction, but further work is required.

A curve typical of the empirical results obtained so far is shown in Figure 9.7, in which values of the normalized matrix element M_{IQ} / M_{II} is plotted as a function of phase angle for all of the measurements made on volcanic cinders. The apparently simple dependence on phase angle suggests fitting the data by a trigonometric relationship of the form

$$x = a + b \cos c\, y \qquad (11)$$

where $x = M_{IQ} / M_{II}$, $y = \theta - \theta_o$, and a, b, and c are parameters which may

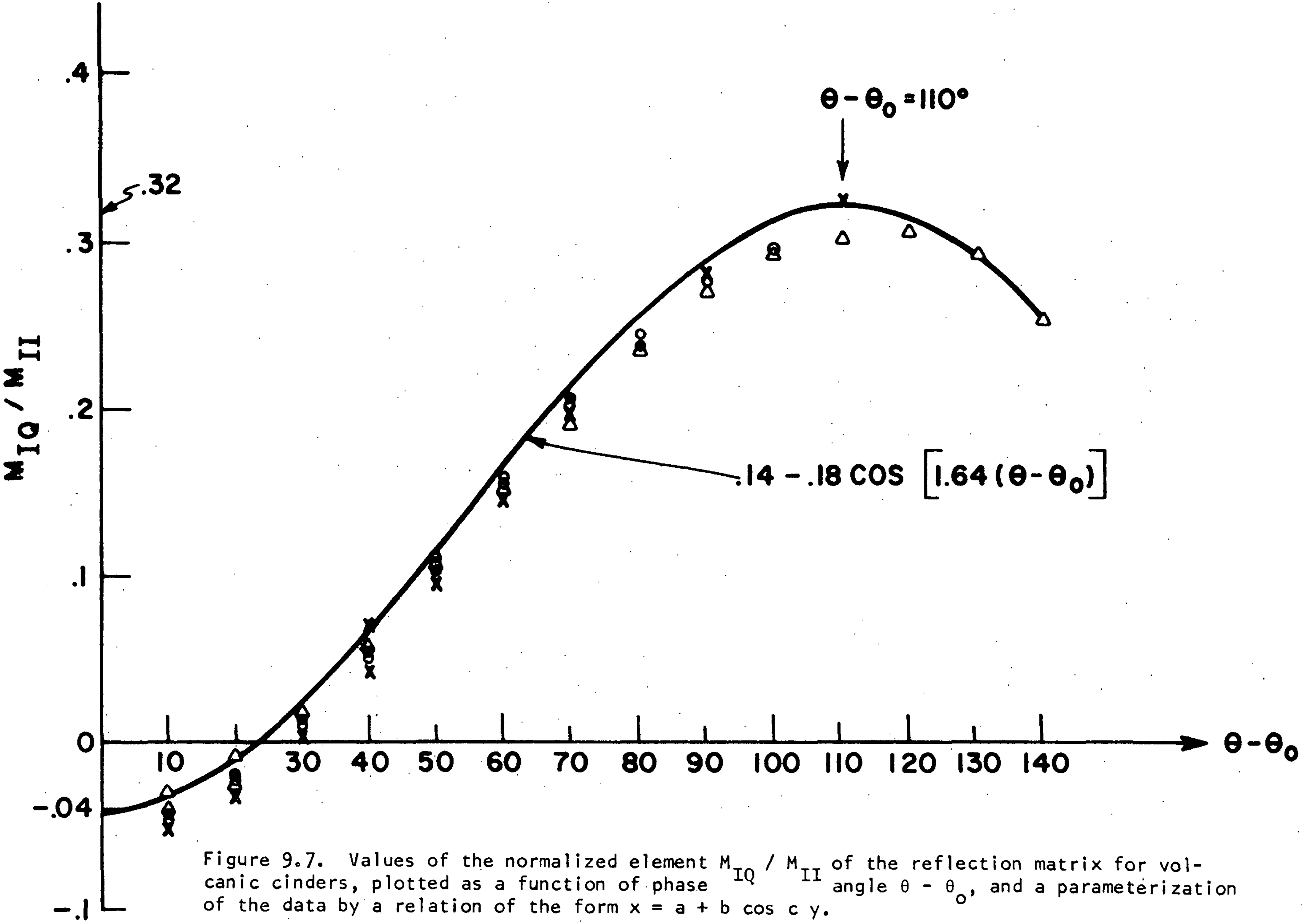

Figure 9.7. Values of the normalized element M_{IQ} / M_{II} of the reflection matrix for volcanic cinders, plotted as a function of phase angle $\theta - \theta_o$, and a parameterization of the data by a relation of the form $x = a + b \cos c\, y$.

be adjusted to achieve the desired fit to the data. For this case we have a = 0.14, b = -0.18, and c = 1.64. The positions of the neutral point and the maximum of the curve are well defined and appear at about the correct positions with respect to the source. The general fit to the data is probably within experimental error.

It is anticipated that further work on the derivation of both empirical parameters and the more physically meaningful parameters for representing the reflection properties of natural surfaces will be a major task during the next period of the investigation.

9.2.3 Design of a Video-polarizer

One of the problems of using information on the polarization field in remote sensing is that of casting the information in a form which is easily grasped by the human brain. An ordinary black-and-white photograph is a very convenient method of presenting information on the intensity field of light as a function of spatial coordinates, and a simple photograph contains a surprisingly large amount of information. A color photograph extends the information content to include both light intensity and its spectral components as a function of position in the scene. Obviously, more information is contained in a color photograph than in a black-and-white photograph, and it is in a form which is readily sensed by the human eye.

In contrast to the intensity field, the field of polarization is not readily sensed by either a photographic emulsion or the human eye. The response to polarized light is about the same as that to unpolarized light, the principal observable being the intensity in both cases. Thus in order to make full use of the polarization field, it is necessary to

find some means of display by which the information is readily transmitted to the human sensor.

The polarization field may be represented in terms of either the well known Stokes parameters or the physically derived quantities of intensity, degree of polarization*, and orientation of the plane of polarization. We choose the latter case, and consider methods of sensing and display of the polarization field for a scene of interest in remote sensing.

It is easily shown that the intensity and complete state of (plane) polarization of a stream of light can be determined by measurements of the intensity transmitted by an analyzer at three different angular orientations with respect to an arbitrary reference direction. The required analysis of the data may be done numerically, but modern electronic devices make it feasible to perform the analysis faster and more conveniently by electronic means. Furthermore, the electronic output is directly applicable to controlling a television system for display of the polarization information. This is the basis for a proposed system for using polarization in remote sensing of the environment.

In general, the information contained in a color television frame is the spatial position of the elements, and the intensity, hue, and saturation of the elements. It should be possible to utilize the signals generated by scans of a scene at the three orientations of the polarizer to control the television system to display the polarization field of the scene. For instance, the scene intensity could control the television intensity, the degree of polarization of the light from the scene could be

*We confine this discussion to the case of plane polarization. The elliptic polarization may also be of interest, but it requires further investigation.

represented in terms of color saturation, and the angle of the plane of polarization could correspond to the hue. Thus all of the information on the polarization of light from a scene, either in a given spectral range or for white light, could be displayed in terms of intensity, saturation, and hue on a color television system. This would make it easy to see at a glance areas of high or low polarization, polarization gradients, and changes of the angle of the plane of polarization. The utility of this information in characterizing surfaces and in discriminating among types of surfaces is still an area for investigation, but in principle it provides additional parameters by which useful results may be achieved.

Considerable work has gone into the design of the polarization display system during this reporting period; its implementation is proposed for the next period of the investigation. A schematic diagram of the system as it is presently planned is shown in Figure 9.8. In the interest of economy in checking out the method, the three television cameras will be replaced by a single camera with different orientations of a single analyzer during the checkout phase. Once the system is proved to be operable and the derived information shown to be of value in remote sensing, the full three-camera system will be developed for general use. However, efforts during the coming period will be devoted to the development and test of the simpler of the two systems.

9.3 FUTURE PROPOSED RESEARCH

The following specific tasks are proposed for the indicated period of the investigation.

9.3.1 Measurements of the Reflection Properties of Natural Surfaces

The computer-controlled polarizing radiometer will be used for determining

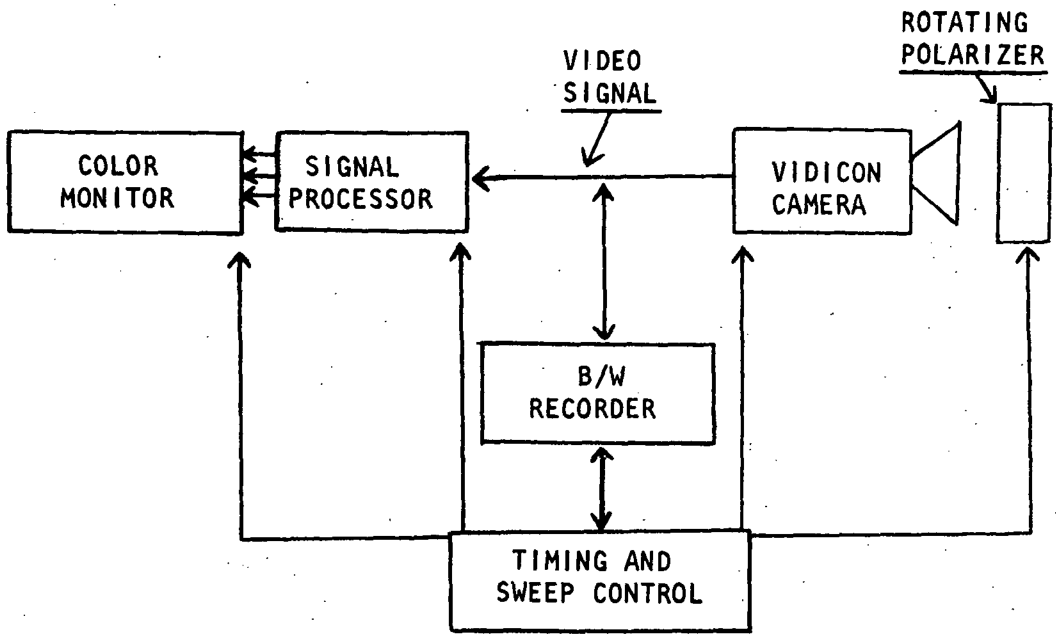

Figure 9.8. Schematic design of a system for a television display of the complete state of linear polarization of light reflected from a natural scene. The system is proposed for use in discriminating among surfaces of interest in remote sensing.

in detail the elements of the reflection matrix for various types of natural surfaces. The present measurements will be extended to azimuths outside the principal plane, thereby providing sufficient information to construct complete hemispheric maps of each of the elements of the reflection matrix. The first series of such measurements will be in the controlled conditions of the laboratory, but later measurements will be under lighting conditions obtained at different times and under various conditions of cloudiness in the natural environment. Emphasis will be on the types of surfaces (agricultural crops, man-made materials for urban use, etc.) of most interest in remote sensing. The output from this measurement program will be basic data on the reflecting and polarizing properties of selected surfaces, which are both of interest directly in surface discrimination and of use in further characteriziation of surface properties.

9.3.2 Parameterization of Surface Reflection

The parameterization of surface reflection will be extended in two directions. First, a representation of the various elements of the reflection matrices of the surfaces will be obtained in terms of a few empirical parameters for practical use in characterizing the surfaces. It may be possible to distinguish among the surface types simply on the basis of the empirical parameters, which would be a significant advance for purposes of remote sensing. There are indications that a given parameter may be representative of two or more of the matrix elements. Efforts will be made to exploit such redundancy if it can be found.

The second type of parameterization will be based on the physical conditions of the problem. The method of approach here will be to interpret

the reflection data in terms of the roughness and index of refraction of the surface material, the ratio of diffuse to specular type of reflection, and the wavelength and angle of incidence of the illuminating radiation. The theoretical work on surface reflection which is already reported in the literature will be applied as appropriate, and the theories will be generalized where possible to yield all of the four Stokes parameters, not being restricted, as in the usual case, to only the reflected intensity. It is hoped that further general relations can be found for representing the polarizing properties of natural surfaces in terms of their physical characteristics and the type and geometry of the incident radiation.

9.3.3 Development of a Video Polarization Sensor and Display

Construction and checkout of the video system mentioned above for the sensing and display of the complete linear polarization field of an illuminated scene will be performed during the coming period. The first model will utilize a simple rotating analyzer placed in front of the lens of a television camera. The most expensive components for the initial system (television camera and color monitor) can be borrowed on a no-cost basis, thereby greatly reducing the expense required for checking out the method. An additional small item for electronic and mechnical components for the initial system is included in the proposed budget. It is anticipated that if the system lives up to expectations and proves to be a valuable tool in remote sensing, the work necessary for a more complete system will be proposed at a later time.

9.5.4 Studies of Radiative Transfer

Numerical studies of radiative transfer in the atmosphere will be an

integral part of the investigation during the coming period. Of particular interest will be computations of contrast transmission coefficients for the various components of polarized light and determinations of the background light against which surface objects must be seen from a remote platform. The computations will utilize programs which already exist, thereby minimizing the cost of program development. Programs for slightly turbid models of the atmosphere, applicable for oceanic areas and continental areas at locations far removed from local sources of particulates, have already been utilized for preliminary calculations. They are available for use on this project. In addition, more sophisticated programs which are adaptable to practically any conditions of atmospheric turbidity have been developed at IBM, Palo Alto under NASA sponsorship. Assurance has been obtained that these most advanced programs can be made available for use in the proposed investigation.

The output anticipated from the computations will consist of all of the four Stokes parameters, together with the derived quantities of degree of polarization and angle of the plane of polarization, as functions of angle of incidence, angle of emergence, and wavelength of the radiation, for a relatively large number of atmospheric models. These data will be used for further computations of contrast transmission and background radiation for the various physical assumptions involved.

9.3.5 Measurements of Skylight Polarization

The polarizing radiometer will be used for a series of skylight measurements, the objective being to provide a check on the theoretical computations. The measurements will be made on the Davis campus, and will be

coordinated with atmospheric aerosol measurements to be made simultaneously by Professor John Carroll with an aircraft-mounted aerosol counter. By this means it will be possible to evaluate the adequacy of the radiative transfer computations by checking them against actual data on the polarization and intensity of the radiation field and on the measured properties of the turbid atmosphere. In addition, an initial study of the problem of inverting the radiation data to give aerosol characteristics will be started.

Chapter 10

ADDITIONAL ACTIVITIES RELATED TO THE INTEGRATED STUDY

10.1 INTRODUCTION

Beginning with the period covered by the present progress report, NASA saw fit to establish an "Administrative Fund" for use in a variety of ways by the principal investigator of this integrated study. The establishment of such a fund had been proposed in our semi-annual progress report of 31 December, 1971 and the rationale for its establishment was set forth in detail in Chapter 11 of that report. Use has now been made of that fund for each of the specific activities previously proposed, and there is abundant evidence throughout our present progress report that the fund, modest in amount though it is, has been paying rich dividends to NASA through more efficient conduct and more effective publicizing of our integrated study. Of special importance has been the increased ability which the fund has given us for present training programs to various potential users of the techniques and information derived through our study.

10.2 PROPOSED CONTINUATION OF THE "ADMINISTRATIVE FUND"

Because of the demonstrated usefulness of this fund, it is proposed that during our next funding period, a modest sum again be set aside for use as an "administrative fund". As explained in the paragraphs which follow, such a fund would continue to be used in part to defray travel expenses for trips within the United States of the types that have been made during the present funding period as described in previous

chapters of this report. Several other important uses of such a fund also are envisaged, however. It is to be emphasized that it was possible, until recently, for our group to draw to a limited extent on funds provided to the Space Sciences Laboratory under the NASA sustaining grant to that laboratory. In fact, NASA urged us to do so. About one year ago, it was decreed, however, that in the future our integrated study should no longer use funds from that grant. As will be indicated in the concluding section of this chapter, the sum that we propose be allocated for this purpose from our existing $500,000 per year grant, is approximately $26,161. Specific uses which we propose be made of such an administrative fund are described in the following paragraphs.

10.2.1 "Seed Funds" for Additional Phases of the Project

It is proposed that some of this administrative money be used as "seed funding" for additional projects which scientists on various campuses of the University of California wish to perform and which both they and we believe eventually could constitute very important parts of our "Integrated Study of Earth Resources in the State of California Using Remote Sensing Techniques". Scientists from various departments at both the Santa Cruz campus and the San Diego campus of the University of California have expressed a strong desire to participate in our "Integrated Study". However, in each case it appears that a limited effort to establish the feasibility of what is being proposed should be made before we attempt to incorporate certain investigators from these additional campuses into our present multi-campus project. Recently the principal investigator for our integrated study visited

at length with both the Chancellor and other key personnel on the Santa Cruz campus relative to their desire to participate in this integrated study in the near future. During the preliminary discussion that was held, several projects of sufficient promise and relevance were proposed to justify the holding of additional meetings at some time in the near future in order to formulate plans for the conduct of limited "feasibility" studies for which only a few hundred or at most a few thousand dollars of financial support would be required.

A similar situation exists with respect to the San Diego campus. Furthermore, there are additional departments in each of the campuses which currently are participating in our integrated study which have expressed desire to perform feasibility studies with limited funding in the hope that such studies would lead to their eventual participation in our integrated study. The proposed "seed funding", menial though it would continue to be, often would permit such feasibility studies to be made.

10.2.2 Funds for Working with Certain Specific User Groups

It also is proposed that a limited amount of this administrative money continue to be made available to our various investigators to permit them to work more closely with certain user groups or individuals who might benefit greatly from some of our findings. For example, during the past year agricultural extension specialists in 33 counties of the State of California have been participating in our studies to one extent or another even though this has been done of necessity without direct NASA funding of their efforts. It is not proposed here that NASA be asked to fund these enthusaistic potential investigators and users.

Instead we merely seek authorization for the continued spending of part of our proposed administrative fund in defraying expenses of various University scientists who presently are participating in the integrated study as they seek to work quite closely with these very able and highly motivated extension specialists. There is a tendency for many of us who are participating in the NASA Earth Resources Survey Program to give lip service quite readily to the concept that we must work closely with potential users of our product, the better to ensure that the product will satisfy "user requirements". We recognize that much can be gained if research findings such as those currently being produced under our integrated study can be promptly disseminated to and evaluated by those who could use such findings to greatest advantage in earth resource management. We can scarcely envisage a more appropriate group with which to work than these 33 university-employed extension specialists, in view of the fact that their primary purpose is to serve as the interface between the research arm of the university, state-wide, and the farmers, foresters and other resource managers within their respective counties.

10.2.3 Funds for Maintaining Certain Specific Types of Liaison

Administrative funds also could be used to excellent advantage and on a continuing basis in providing the necessary liaison beyond that for which our integrated study budgets, project-by-project, will allow. For example, it is apparent that the number of visiting scientists, both foreign and domestic, who present legitimate requests that they be conducted on tours of our various test sites, is rapidly increasing. On

those occasions when we have been able to accede to such requests our efforts have been warmly received and highly praised. Until a year ago, these efforts had been restricted primarily by budget considerations since no funds had been provided under our integrated study for such activities. During the past year, however, we have demonstrated that even a limited amount of financial support for this kind of activity can be of great benefit to the NASA Earth Resources Survey Program, in general, and to our phase of the work in particular.

10.2.4 Funds for Intra-Campus and Intra-U.S. Travel by the Principal Investigator

Corollary to several of the above-mentioned considerations, as scientists from additional departments and campuses become involved in our integrated study, it becomes desirable that more frequent and extensive trips to various campuses and field sites be made by the principal investigator, again using limited amounts of the administrative fund for this purpose. Similarly, as documented in Section 10.1, certain kinds of travel within the United States which NASA expects the principal investigator to perform in support of our integrated study are best financed from an administrative fund of the type which has been available to us during the past year.

10.2.5 Cost of Materials Needed in Compiling and Reproducing Our Project Reports

The cost of "continuous tone" photographs and other materials needed in producing the required 40 copies of our interim reports and annual progress reports likewise is now being borne by the administrative fund. Since the principal investigator in each instance compiles reports from

project participants on the several campuses and integrates these into our composite report, an "administrative fund" has been found during the past year to be a logical source of the money needed for this purpose. Hence, continued funding of the same type, and for the same purpose, is hereby proposed.

10.2.6 <u>Half-Time Salary for a Secretary</u>

It has been recognized by NASA from the start of our project that funds would be needed to pay the half-time salary of a secretary who would not only type and collate our interim reports and progress reports but also assist the principal investigator in preparing correspondence related to the integrated study. Consequently, the NASA monitors initially approved our obtaining the necessary funds from the NASA sustaining grant which is given each year to the Space Sciences Laboratory. Since, as previously mentioned, the sustaining grant funds should no longer be used for such purposes, it is considered appropriate for us to continue to use the proposed administrative fund, as in the past year, to pay the half-time salary of a secretary.